PRELIMINARY REPORT.

PETROLEUM AND GAS.

ORTON.

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GEOLOGICAL SURVEY OF OHIO.

PRELIMINARY REPORT

UPON

PETROLEUM AND INFLAMMABLE GAS,

—BY—

EDWARD ORTON, STATE GEOLOGIST.

REPRINTED FOR THE AUTHOR

WITH A

SUPPLEMENT.

COLUMBUS, O.:
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PREFACE.

THE original edition of the Preliminary Report on Oil and Gas in Ohio, by Edward Orton, State Geologist, consisting of twenty-five hundred copies, was published by order of the Legislature of Ohio in June, 1886, and was distributed by the members of the Legislature. No copies were placed on sale. The recent interest in natural gas and petroleum awakened in this and adjoining States by the experience of Pittsburgh, and also by the astonishing developments at Findlay and Lima, has led to an eager and general demand for information upon these subjects, and all available sources of knowledge are brought into requisition. The inquiry for this Preliminary Report has been wide-spread and it still continues. In view of this demand, it was suggested to the proper committees of the Legislature, at its late session, that it might be well to reprint the Report and thus meet this continued demand, but inasmuch as Volume VI was about to be ordered it seemed to the committees unnecessary to anticipate it further. There was, however, considerable delay in providing for the publication of Volume VI. It was presented to the Legislature on the first day of February, but the necessary legislation pertaining to its publication was not consummated until the middle of March. While every effort will be made to expedite its issue, it is plain that a number of months must elapse before the volume will be ready for distribution. But the demand for information on geological points involved in present explorations is constantly increasing, and therefore the author has decided to fill the gap, as far as demands are made upon him, by the reprint of this Preliminary Report, and thus to put the information that it contains within the reach of those who desire it.

The Report is educational in aim and character, and it undertakes to set forth sound and conservative geological answers to many of the questions that the people of this and adjoining States are so earnestly asking at the present time. It is obviously desirable that this popular demand for the teachings of science on the important practical interests involved should be met as fully and promptly as possible.

The present volume contains, as its name implies, an exact reprint of the Preliminary Report of 1886. The past year has been fruitful in additions to our knowledge of the geology of the State. Never before in its history have such

opportunities been afforded to learn the details of its stratigraphical order and its structural arrangement. If the author were to write with present knowledge a report of the same scope as that published last year, he would find it necessary to change a number of statements, especially in regard to the geological scale of the State, while the facts of development of oil and gas territory would require a very different presentation. The Preliminary Report is, however, reprinted in its original form in this new edition mainly for two reasons: first, to avoid confusion in quotations from it and references to it that may be hereafter made, and second, from the lack of time to re-write and re-cast the sections that especially need revision. It may be further urged that it will aid in the realization of the astonishing developments that are being made in North-western Ohio, if we have before us a picture of the facts as they appeared in 1886.

A supplement is added, in which the proper corrections, rendered necessary by the discoveries of the last year, are given, and the extensions and the present status of the gas and oil fields of Western Ohio are also briefly pointed out. The production of a number of the most important gas and oil wells is also given. A few statements are also added pertaining to the very encouraging recent experience of Indiana towns in the search for natural gas.

The geological map of the first edition is replaced by a map showing the gas fields of the State as at present developed. An interesting and instructive map is added, showing the topography of the Trenton limestone in Western Ohio and also giving indications of its level in Eastern Indiana.

E. O.

Columbus, O., April 15, 1887.

PETROLEUM AND INFLAMMABLE GAS

IN OHIO.

PRELIMINARY REPORT

BY

EDWARD ORTON, STATE GEOLOGIST,

SECTION I.—INTRODUCTION.

An Act of the Legislature, passed May 1st, 1885, made it the duty of the State Geologist to put into the hands of the Supervisor of Public Printing, ready for publication, on or before October 1st, 1885, the manuscript of a chapter on *Petroleum and Inflammable Gas in Ohio*, with suitable maps and illustrations, which chapter was to constitute a part of the volume on Economic Geology, the preparation of which was ordered by the act above named.

During the summer and autumn of 1885, however, the explorations for natural gas and oil were going on with more force than ever before in the State, and new facts in regard to their distribution were constantly coming to light in various quarters. The subjects were acquiring very much more economic importance than they had previously possessed, so that the chapter upon these subjects that was planned for the new volume on Economic Geology was found to be out of proportion and inadequate to their present and rapidly growing importance. The original chapter, in short, it was found necessary to expand into six or eight chapters in order to cover properly the new fields and the new facts. In other words, the chapter was growing to the size of a volume.

It was therefore concluded that the proper policy was to hold back this manuscript until the assembling of the Legislature in January, 1886, when the facts of the case could be stated and

suitable provision could be made, if deemed best, for the publication of all the work prepared.

The attention of the Committees on the Geological Survey in Senate and House was promptly invited to the facts here stated and immediate action was requested.

The result of the consideration of the question by the House Committee was the introduction of a bill by Hon. T. F. McClure, of Vinton county, Chairman of the Committee, providing for the publication of the chapters on Petroleum and Natural Gas, under the title of Volume VI, Geology of Ohio. The chapters submitted and which were to constitute the new volume were the following:

CHAPTER I. *The Geology of Ohio, reviewed with reference to Oil and Gas* (with a Geological Map of the State).
CHAPTER II. *The Origin and Modes of Accumulation of Oil and Gas.*
CHAPTER III. *The Trenton Limestone in Ohio as a source of Oil and Gas.*
CHAPTER IV. *The Berea Grit in Ohio as a source of Oil and Gas.*
CHAPTER V. *The Remaining Horizons of Oil and Gas in Ohio.*
CHAPTER VI. *The Macksburg Oil Field*, by F. W. Minshall.
CHAPTER VII. *Methods of Drilling Oil and Gas Wells*, by Fred. H. Newell.
CHAPTER VIII. *The Uses of Natural Gas and the Methods of Using*, by Emerson McMillin.
CHAPTER IX. *Table of Elevations above Sea level of localities in Ohio*, by Professor C. N. Brown.

The bill required that the manuscript should be delivered to the Supervisor of Public Printing on or before May 1st, 1886. It was estimated that this volume would consist of 400 to 500 pages, aside from the maps and illustrations.

The bill passed the House of Representatives with but a single opposing vote, but when it came to the Senate Committee on Geology it did not secure the same favorable regard. The Committee foresaw that the publication of the chapters on oil and gas at the present time would necessitate the publication of another volume at an early date on the remaining subjects embraced in the bill by which the preparation of the new material was provided for, and accordingly they counted it better to hold back the chapters above named until the remaining subjects could also be included. A bill embodying these provisions and fixing February 1st, 1887, as the date for the completion of the entire volume, was introduced into the Senate on May 10th, 1886, by Hon. A. W. Glazier, of Washington county, and was passed by the Senate on May 12th. The bill also required the State Geologist to prepare an abstract

of the results of his investigation on oil and gas, to be ready for publication on or before June 15th, 1886, said abstract to be provided for from the appropriation of May 1st, 1885. This bill passed the House on May 15th and became a law.

The present paper has been prepared in compliance with this action. It contains some of the general statements pertaining to the subjects, and some of the more important results of the investigations of the survey for the last year. No further use will be made of the abstract herewith printed, but in subsequent publications it is expected that the chapters above referred to will find place, in which more extended and orderly discussions of these topics are contained than would be proper here.

THE ORIGIN OF THE NEW INTEREST IN NATURAL GAS.

The introduction and use of natural gas on the large scale that has been in progress in Pittsburgh for the last three years has made a profound impression upon competing manufacturing centers, especially upon the towns and cities of eastern Ohio. The cheapness of the new fuel, the economy resulting from several different factors in its use, the improvement of product in a number of lines of manufacture, all combine to give a decided advantage to the centers that have been fortunate enough to secure it, and to make competition seem almost hopeless to the towns that are without it.

In consequence, an earnest and eager search for natural gas has been begun and maintained in eastern Ohio. A large amount of money has been spent, and more is being freely spent in seeking to discover sources of gas adequate to the new demand within practical distances.

The interest awakened in the new fuel has not been confined, however, to the regions in most direct proximity to the Pittsburgh field, but north-western Ohio has also been stimulated to try the fortunes of the drill. The geological range and conditions of eastern and western Ohio are quite unlike, and inferences from one field cannot be safely carried to the other, but to many people the drilling of a well 1,000 or 1,500 feet deep in one place seems very much the same as drilling to an equal depth in any other, and conclusions as to the probable results, however unwarranted, are confidently drawn. The occurrence of high-pressure gas at a

depth of 1,200 to 1,800 feet in the Ohio valley, for example, gives no warrant whatever for expecting to find high-pressure gas at the same depth in the Maumee or the Miami valleys. But fortunately, the search which was thus begun and conducted, has resulted in the discovery of a new horizon of petroleum and gas in western Ohio, which now promises to be the most valuable of our entire series.

In November, 1884, high pressure gas was discovered at a depth of about 1,100 feet, in Findlay, Hancock county. The surface signs of gas were very obvious and abundant there, and had been noticed and recorded since the county was first settled, but the source had not been discovered nor even conjectured. It was a complete geological surprise to find the Trenton limestone, one of the most wide-spread and important strata of Lower Silurian age in North America, but which nowhere rises to the surface in Ohio, a source of gas and later of oil in large amount and of great value. This limestone was known to be petroliferous to a small extent in Canada, it is true, and in Kentucky and Tennessee also it had been known to yield oil and gas in quantity, but it had been repeatedly tapped at various depths and at various points in Ohio "without a sign," and consequently there was nothing to warrant a geological expectation of such a discovery here. In fact, the drilling might have been done almost anywhere else, as the results are showing, without any large success. Out of scores of trials already made, there are but three or four centers of any important production so far reached in this part of Ohio. But a flame shot up from the pioneer well at Findlay that showed to the people of that entire section that a new source of light and heat and power was now available, at least to some small portions of the county.

Findlay became to northern Ohio and Indiana what Pittsburgh was to the eastern portion of the State. Her success incited every ambitious and prosperous town to send the drill to the new horizon to see what was there held in store. It so happened that two of the towns that first followed her example were successful—Bowling Green in reaching a moderate supply of gas, and Lima, in finding oil. These early successes almost exhaust the list of successes to the present time, but they greatly increased the ardor and enthusiasm of the early search throughout northern Ohio. While the

work of exploration is still going forward on a large scale, the many failures that have occurred have sobered the judgment of the people to some extent, and those that drill now recognize the great uncertainty involved. They see that to secure a valuable supply of natural gas, something more than the drilling of a deep hole into the earth is essential, and all of the questions connected with the origin and accumulation of gas and oil are discussed with more interest than ever before.

ORIGIN OF PETROLEUM AND GAS.

It is not necessary to consider the origin of natural gas and petroleum separately. They have a common history. They are produced from the same sources, accumulated by similar agencies, and stored in the same reservoirs. In order of formation, petroleum is probably first. It is the more complex in composition and thus nearer to the organic world from which it is derived. Gas is the same substance on the downward road to the simplicity of inorganic compounds. No process is known by which gas is built up into oil, but the breaking up of petroleum into gaseous products is seen to be constantly going forward in nature, and it is also effected in the large way artificially.

Petroleum never exists free from gas, but it is sometimes asserted that gas is found that has no connection with petroleum. This claim is probably a mistaken one, and if the dryest gas could be followed throughout its underground reservoirs, it is altogether probable that accumulations of oil would be found along the line in every case. There is no horizon known that produces either substance to the entire exclusion of the other.

As already implied, petroleum and gas are derived from the organic world. Both vegetable and animal substances have contributed to the supplies, and these separate sources give different characters to their products, as will be presently shown. There are certain other theories in regard to the origin of petroleum, it is true, which have been advanced by eminent chemists, but which do not match at all well with the geological facts involved. These last named theories refer petroleum to peculiar decompositions chiefly of water and carbonic acid which are supposed to be carried on at considerable depths in the earth where these substances are brought into contact with metallic iron or with the metallic bases

of the alkalies at high temperatures. Never were more artificial or unverifiable theories presented for the explanation of natural phenomena, and it is surprising that they should have obtained any currency whatever. Something might be said for them, perhaps, if we had no other possible way of accounting for the facts to which they refer, but when they are compared with the theories of organic origin they have no standing-ground. The truth is, we are constantly manufacturing from animal and vegetable substances in the large way, both gas and oil that are fairly comparable in both chemical and physical characteristics, with the natural products. Further, we find vegetable substances passing by natural processes into petroleum and allied compounds, so that there is no need whatever to invent a strained and fantastic theory based on remote chemical possibilities, in order to cover the ground. These chemical theories teach that the process of oil and gas formation is a continuous one, and no reason is apparent why stocks may not be maintained from such a source even when they are drawn upon. Perhaps it is this feature that has recommended these theories more than any other. Any doctrine that gives us unwasting supplies of force is sure to be popular as long as it can find the semblance of justification, as witness the hold that the claims for perpetual motion have on the public mind.

The petroleum and gas of shales and sandstones are in the main derived from vegetable matter, and as the principal stocks are found in sandstones, vegetable matter may be said to be the chief source. The oil and gas of limestones are presumably derived from animal matter, inasmuch as the limestones themselves are known to be, in the main, a product of animal life.

The vegetation principally employed in this production is of the lower kinds, sea-weeds and other allied groups being altogether the most conspicuous elements. The animal life represented in limestone oil, and gas, is also of the lower groups. Plants may have been associated also with animal matter in the formation of limestone oil, to some extent.

HOW WAS PETROLEUM FORMED?

To the question, *how were these bodies formed out of organic matter?* there are various answers.

They are most commonly referred to the agency of distilla-

tion. Destructive distillation consists in the decomposition of animal or vegetable substances at high temperatures in the absence of air. Gaseous and semi-liquid products are evolved, and a coke or carbon residue remains behind. The "high temperatures" in the definition given above, must be understood to cover a considerable range, the lower limit of which may not exceed 400 or 500 degrees F.

Petroleum and gas on the large scale are not the products of destructive distillation. If shales, sandstones, or limestones holding large quantities of organic matter, as they often do, and buried at a considerable depth, should be subjected to volcanic heat in any way, there is no reason to doubt that petroleum and gas would result from this action. Without question, there are such cases in volcanic districts, but the regions of great petroleum production are remarkably free from all igneous intrusions, and from all signs of excessive or abnormal temperatures. All claims for an igneous origin of these substances are emphatically negatived by the condition of the rocks that contain them.

There is a statement of the distillation theory that has attained quite wide acceptance, which needs to be mentioned here. It is to the effect that these substances, oil and gas, have resulted from what is called "spontaneous distillation at low temperatures," and by low temperatures, ordinary temperatures are meant. It does not, however, appear on what facts in nature or upon what artificial processes this claim is based. Destructive distillation is the only process known to science under the name of distillation, which can account for the origin of oil or gas, and this does not go on at ordinary or low temperatures. A process that goes on at ordinary temperatures is certainly not destructive distillation. It may be chemical decomposition, but this process has a name and place of its own, and does not need to be masked under a new and misleading designation, such as spontaneous distillation. No help can come to us, therefore, from the adoption of the spontaneous distillation theory.

It seems more probable that these substances result from the primary chemical decomposition of organic substances buried with the forming rocks, and that they are retained as petroleum in the rocks from the date of their formation. It is true that our knowledge of these processes is inadequate, but there are many facts on

record that go to show that petroleum formation is not a lost art of nature, but that the work still goes on under favorable conditions. It is very likely true that, as in coal formation, the conditions most favorable for large production no longer occur, but enough remains to show the steps by which the work is done.

The "spontaneous distillation" theory has probably some apparent support in the fact that must be mentioned here, viz: that where petroleum is stored in a rock, gas may be constantly escaping from it, constituting, in part, the surface indications that we hear so much of in oil fields. The Ohio shale, for example, is a formation that yields along its outcrops oil and gas almost everywhere, but no recent origin is needed for either. The oil may be part of a primitive store, slowly escaping to the day, and the gas may be constantly derived from the partial breaking up of the oil that is held in the shales. The term "spontaneous distillation" might, with a little latitude, be applied to this last named stage, but it has nothing to do with the origin of either substance.

While our knowledge of the formation of petroleum is still incomplete and inadequate, the following statements in regard to it are offered as embodying the most probable view:

1. Petroleum is derived from vegetable and animal substances that were deposited in or associated with the forming rocks.

2. Petroleum is not in any sense a product of destructive distillation, but is the result of a peculiar chemical decomposition by which the organic matter passes at once into this or allied products. It is the result of the primary decomposition of organic matter.

3. The organic matter still contained in the rocks can be converted into gas and oil by destructive distillation, but so far as we know, in no other way. It is not capable of furnishing any new supply of petroleum under normal conditions.

4. Petroleum is, in the main, contemporaneous with the rocks that contain it. It was formed at or about the time that these strata were deposited.

THE DISTRIBUTION OF PETROLEUM AND GAS.

Contrary to a commonly received opinion, petroleum and gas are very widely distributed and very abundant substances. The drill can scarcely descend for even a few hundred feet at any point in Ohio without showing the presence of one or both of them. The rocks of the State series can be roughly divided into three

great groups—limestones, sandstones and shales. Petroleum is found abundantly in each of these groups. The percentage is small, but the aggregate is large. It is equally, or at least generally diffused throughout certain strata, while in others it is confined to particular portions or beds. An example of the first case is found in the Ohio shale. The Ohio shale, Cleveland—Erie—Huron, of earlier reports, consists of a series of homogeneous, fine-grained deposits, black, blue and gray in color, 300 feet thick on their western outcrop in central Ohio, but more than 1,800 feet thick under cover in eastern Ohio. This entire formation is petroliferous, as is proved by an examination of drillings that represent the whole section. The black bands are probably most heavily charged. The chemist of the survey, Professor N. W. Lord, finds two-tenths of one per cent. of petroleum *as such*, present in these bands, and is certain from the nature of the processes that he was obliged to employ, that the entire amount is not reported. But, estimating the percentage to be but one-tenth of one per cent. in place of two-tenths, and calculating the thickness of the shale at its minimum, viz: 300 feet, we find the total stock of petroleum held in the shale to be 1,560,000 bbls. to the square mile, or nearly twice as large an amount as has ever been obtained from any square mile of the Pennsylvania fields.

Of the limestones of the State, the Water lime, or Lower Helderberg limestone, is probably the most heavily and persistently charged with petroleum. Drillings taken from this stratum at a depth of 400 to 500 feet below the surface in the trial well now being sunk at Columbus, are found by Professor Lord to have the same amount of free petroleum that the black shale contains, viz: two-tenths of one per cent. The limestone has the same thickness that is assigned to the shale on its outcrop, viz: 300 feet. The figures, therefore, duplicate those already given. The total amount of oil exceeds 3,000,000 bbls. to the square mile.

All the other great limestones of our series carry petroleum, at least in certain beds. The Clinton limestone is often an oil-bearing rock, and the show of its outcrop has led to the sinking of a number of wells in search of oil, in past years. The Niagara limestone is highly bituminous in places. Asphaltic grains, films and masses constitute as much as 4 or 5 per cent. of its substance at several points in the State. The Corniferous limestone is also

distinctly bituminous in some of its beds. The limestones of the Cincinnati group also carry a determinable amount of petroleum.

As for sandstones, all know that it is in them that the main stocks of petroleum have thus far been found, but there is good reason to believe that these stocks are not native in the sandstones, but have been acquired by them subsequent to their formation. This point will be considered further, under another head.

MODES OF ACCUMULATION OF PETROLEUM AND GAS.

In the accumulation of petroleum, two stages are to be noted, viz: a primary and a secondary stage. The first is concerned with the retention of petroleum in the rocks, and might have been with equal propriety treated under the preceding head. The second stage is concerned with the origin and maintenance of the great stocks of oil and high-pressure gas, in which all the value attached to these substances lies. Both are connected with the composition of the rock series in which oil and gas are found, and the latter is also greatly affected by the arrangement and inclinations of the rock masses, or in other words, by their *structure*.

The primary accumulation of petroleum or its retention in the rocks in a diffused or distributed state, seems to be connected with the composition of the series to a great degree. The great shale formation of Devonian and Subcarboniferous ages that separates the Berea grit from the Devonian limestone, the western edge of which shale formation, outcropping in central Ohio, is known as the Ohio shale (Cleveland, Erie, Huron), is unmistakably the source of the greatest accumulations of oil and gas, so far found, in the country. It holds thus far, as decided, a superiority to all other sources, as the Appalachian coal field does to all other sources of fossil fuel. The accumulation of petroleum in this great shale formation is no accident. It depends on two factors, viz: the abundance of vegetable matter associated with the shales in their formation, which is attested by the large amount still included in them, and upon the affinity of clay for oil. The last named point is an important one. Clay has a strong affinity for oil of all sorts, and absorbs it and unites with it whenever the two substances are brought into contact. Professor Joseph Leidy made the interesting observation a number of years since, that the bed of the Schuylkill River in Philadelphia, below the gas works, was covered with an

accumulation of the oily matters that are always formed in the process of gas-making. As these substances are lighter than water and float upon its surface naturally, it was at first sight hard to understand how they could have been carried to the river bed, but it was soon learned that the clay of the river water absorbed the oils as they were floating along, and finally sank with them to the river floor. In a similar way we may suppose the primary accumulation of petroleum in the shales to have been in part accomplished. The oil set free by vegetable decomposition around the shores or beneath the waters of a sargasso sea, would be arrested by the fine-grained clay that was floating in the water, and would have sunk with it to the sea floor, forming this homogeneous shale formation that we are now considering. Sand would have no such collecting power.

The distribution of petroleum through limestone is not as easily explained, but it may be in part dependent on the presence of the same element, viz: clay. In almost all limestones, there is a percentage of clay present, and frequently it rises to a conspicuous amount. Oil is held in both magnesian limestones and in true limestones in Ohio. The magnesian limestones are largely in excess in the series of the State, and it so happens that all of the most petroliferous strata are magnesian in composition, but this fact is probably without significance in this connection.

Petroleum distributed through shales or limestones in the low percentages already named, although the total amount held may be large, is of no economic value. Like other forms of mineral wealth, it must be concentrated by some natural agencies before it can become serviceable in any way. This brings us to consider the secondary accumulation of petroleum already referred to, by means of which all the great stocks have been formed and maintained. This constitutes one of the most important subjects in the entire history of petroleum. The sources of oil and gas are very wide-spread, as has already been shown, but the concentrated supplies are few and far between. To learn the horizons and locations of these supplies is the condition of most successful operations in the production of oil and gas, and it is in this field that the most important practical applications of geology to these subjects are to be found.

OIL GROUPS.

As the experience of the last thirty years has abundantly shown, an oil or gas series always consists of two elements, viz: a porous rock or *reservoir*, overlain by a close and fine-grained impervious rock or cover. A third element must always be added to make out the logical series, viz: an underlying or associated source of oil and gas. It is obvious that the last named element is first in order and in importance, but for reasons already given in part, and for others that are not hard to find, practically we have less to do with it than with the two former elements. It will be borne in mind that the sources of petroleum are well-nigh universal, and also that they have no economic value, and are therefore seldom penetrated by the drill. The search generally terminates in the reservoir. The great sources of the Ohio scale are, as already implied, shales and limestones, both more or less bituminous. These sources have done their work wherever large accumulation is found, and where no accumulations exist the petroleum occurs, as already shown, in large but valueless stocks distributed through the body of the strata.

THE RESERVOIR.

The reservoirs must be porous rocks. In all of the experience in the great fields of Pennsylvania and New York, the rocks in which the large stocks of oil and gas were found were, without exception, sandstones or conglomerates. To them the driller early gave the name of "oil sands," and this name is in universal use. The grain and thickness of these sandstones are found to be important factors in their production. Other things being equal, the coarser the grain and the thicker the stratum, the greater is its production found to be. Mr. J. F. Carll, of the Pennsylvania Geological Survey, our highest authority in regard to petroleum production, has shown that an oil sand can hold one-tenth of its bulk of oil, and he believes that it may contain under pressure as much as one-eighth of its bulk. This would give 1½ inches of oil to every foot of the oil sand.

Taking the most productive portions of the latter in the Venango field to be 15 feet, we find in that district a possible capacity of 9,600,000 barrels per square mile, an amount, it is needless to say, vastly in excess of any production ever known.— (2d Penna. Survey, Oil Regions, III. pp. 252–53.)

The driller places great reliance on the oil sand, and learns to draw conclusions and make forecasts from its character more than from any other single element that he encounters.

It has been a great geological surprise to find, as we have found in Ohio within the last two years, a reservoir of high pressure gas and large oil wells in a rock of altogether different character from the oil rocks already described. The new oil and gas rock of north-western Ohio is a magnesian limestone of ordinary type. The driller, all of whose traditions as a rule are derived from the eastern oil field, cannot call the new oil rock by any other name than the familiar one which has satisfied all of his experience hitherto, viz: an oil sand. Accordingly, good Trenton limestone, pure enough to be burned for lime in many instances, is styled the *oil sand,* and the old standards of judgment, applicable to sandstones alone, are applied to the new rock. Its grain is discussed, when, strictly speaking, it has no grain. Some separate the upper productive belt from the underlying rock, calling the upper only the oil sand, and recognizing that which is found below as Trenton limestone. This is a distinction without a difference. There is no sandstone of any sort within 500 feet on either side, above or below, the gas rock of Findlay or the oil rock of Lima (which are one and the same thing), so far as explorations to the present time have shown. The gas rock and oil rock are in many instances exceptionally pure magnesian limestones. The structure of the rock, as shown by good-sized fragments brought up from the wells after the use of torpedoes, or sometimes by the pressure of the escaping gas, shows the rock to be moderately porous. Its porosity is due to the interlocking of its crystalline growths. If the rock is drilled small, there is nothing to show this porous character or the absence of it, and all inferences from the appearance of such drillings or oil sands, as they are styled, as to the productive power of the rock, are deceptive. They have no basis in fact. There need be no long argument over the composition of the oil rock. Sandstone does not dissolve in the ordinary mineral acids, while limestone does. If any one wishes to settle for himself the character of the oil rock of the new field, let him expose it to the action of dilute hydrochloric (muriatic) acid, which can be obtained at any drug store. Magnesian limestones do not dissolve as promptly as calcareous limestones, but with time enough they

are decomposed. The following analysis (1) shows the composition of the oil rock, as brought up in a large fragment from the Woolsey well in Lima. The composition of the drillings of the oil rock from another well, in the same town, are also given in the table (2):

	1	2
Carbonate of lime	55.90	52.66
Carbonate of magnesia	38.85	37.53
Alumina and iron	2.94	....
Silica	.75	....

The first well is a small producer, in fact, is nearly a failure; the second is one of the productive wells of the field.

In the case of the new oil field, the reservoir is apparently continuous with the source of the oil. The source seems to be the entire rock, as the drillings from all depths are often found to be petroliferous, but the accumulation takes place in the upper beds only.

Besides sandstones and limestones, shales also serve to a small extent as receptacles of accumulated oil and gas in Ohio. The character of the containing rock in these cases is not well known. Generally, the gas is of light pressure, but it is a fairly persistent supply that is found in these rocks. The belt of shales along the shore of Lake Erie gives the examples of this sort of accumulation and supply. These shales, where productive of gas, are found to consist of hard and light-colored bands, interstratified with dark bands, the gas appearing to be found when the harder bands are penetrated. The production of oil from these sources is always small, but as already stated, fair amounts of gas are sometimes derived from them.

Petroleum and gas are not the only substances that are found in these reservoirs. Salt water is almost an invariable accompaniment of both. The oil rocks are salt rocks as well, in some parts of their extent. The distribution of these three substances in the same stratum is connected with facts of structure, as will presently be shown. These reservoirs have been described as porous of necessity. The porosity insures a large amount of lateral permeability, a fact of great importance in the distribution of these sub-

stances. The reservoir is often common for large areas. All the wells in a field find the same pressure of gas or oil, even though their production may be very unequal.

THE COVER.

Inasmuch as the three elements, source, reservoir and cover, are all indispensable, it is not necessary to compare their relative importance. It is, however, true that the first and second conditions of accumulation are met more frequently than the third. The cover of every productive oil rock is a large body of fine-grained, impervious clay shale—the finer and more nearly impervious the better. Whenever such a body of shale is found in the Ohio scale, the rock directly underlying, if a sandstone or limestone, is found to contain, in some portions, accumulations of gas and oil. The stocks may be too small to be valuable, but the presence of the shale cover seems to ensure some concentration in these situations. There are three points in the Ohio series of rocks where such shale covers occur, viz: at the surface of the Trenton limestone, where 800 to 1,000 feet of shales and intercalated beds of limestone of the Medina, Hudson River, and Utica epochs are found, at the surface of the Corniferous limestone, which is covered by 300 to 1,800 feet of the Ohio shale, and at the surface of the Berea grit, which is overlain by the best cover of the entire series, viz: the close-grained and nearly homogeneous Cuyahoga shale, 300 to 500 feet in thickness. Two of these, the first and the last, constitute the two main horizons of oil and gas in Ohio. The third is not notably productive thus far in Ohio, but it is the source of the oil supply of western Canada.

The composition of an oil-producing series is thus seen to be essential to its functions. The order already pointed out cannot be departed from, but there must always be—1, an impervious cover; 2, a porous reservoir; and underneath the reservoir the source is to be found.

STRUCTURE AS AFFECTING OIL AND GAS ACCUMULATION.

But this order of arrangement is not enough in itself to ensure any large concentration of oil or gas at any particular place. One other factor must be introduced, viz: *structure*. The strata which constitute the geological scale of the State nowhere lie, for any

considerable extent, in horizontal planes. They are all more or less inclined. Sometimes they are bent into low folds or arches, and sometimes, though very rarely, there are abrupt descents and fractures. As a rule the dip, or angle of inclination to the horizon, of Ohio rocks is very small. It is better expressed as a fall of so many feet to the mile, than by angular measurements, which very seldom rise to one degree. Both the rate and the direction of the descent are uniform over large areas. The average dip for important portions of the State, is between 20 and 30 feet; the direction depends, of course, upon the part of the State which is to be considered.

The movements of the strata here referred to have exerted a very important influence on the concentration of oil and gas in the reservoirs already described. If one of these sandstone strata, filled with salt water, oil and gas, and freely permeable laterally and horizontally for even miles at a time, were to be thrown into a system of low folds, what effect would this movement have upon the contents of the stratum? Would not a separation of gas, oil and water be sure to follow, the gas finding its way to the summits of the arches, and the salt water sinking to the bottoms of the troughs? Such a result would be inevitable under the conditions assumed.

The summits of the folds are called anticlinals, and the troughs synclinals. The lines of direction of the anticlinals are called their axes. The influence of these facts of structure on gas and oil accumulation has been long recognized, or at least asserted, but there is not full agreement as to the part that it plays in the great fields among the geologists who have given most study to the subjects. Professor I. C. White, of Morgantown, W. Va., has recently formulated a theory as to the occurrence of the large stocks of natural gas, which is known as the anticlinal theory of gas. He holds that the theory is susceptible of application to all gas territory, and that it can be made to render practical service of great value by pointing out localities in which drilling may be successful, and especially by indicating the large districts where, from the nature of things, it must be fruitless. The latter service he counts the more important, as large expenditures are going on at random throughout the field, from which nothing can be reasonably expected.

The discussion of these subjects at the present time is giving us a large amount of valuable literature.

All who are engaged in the discussion recognize structure as one of the factors in oil and gas production, but some geologists, as Ashburner and Carll, apparently relegate it to a secondary place, counting the facts treated of under the previous head, viz: the composition of the series, of more importance in this connection. The character and thickness of the strata in which the gas and oil are contained, the nature of the supply from which their stocks are derived, factors like these are considered by them of more moment than the angles at which the strata lie.

The facts that have come to light in the recent investigations of these subjects in Ohio, seem to show the paramount influence of structure upon oil and gas accumulation. In the old fields and in the new alike, irregularities of dip, involving change of direction, suspension, or unusual increase, have been found connected with the large production of both oil and gas in every instance where careful examination has been made. The composition of the series involved is identical for many thousand square miles, but so long as uniformity of dip is maintained, there is no valuable accumulation. As soon, however, as this uniformity is broken in upon, the valuable stocks of gas and oil came to light.

The "belt lines," in which the practical oil well driller and operator of the main field puts so much confidence, so far as they stand for facts of nature, are probably structural lines. A map of the various centers of petroleum in the old field shows that all extend in the north-easterly course which the main structural features of this part of the continent follow. The driller believes fortune to lie in the 45° or 22½ line which leads out in a north-east or south-west direction from each center of production. Experience justifies, to a certain extent, his confidence. The productive gas territory upon which Pittsburgh now depends, is limited to the summits of a few well-marked anticlinals, which all have a north-easterly trend. In regard to the latter, question can scarcely be raised. The predominant influence of structure is obvious. It seems probable that a careful enough system of measurements will show like lines of modified dip to traverse the great oil fields of Pennsylvania and New York.

The occurrence of gas and oil in almost all rocks that have a

heavy shale cover would seem to result from exchanges affected by gravity. The oil is associated with salt water in the stratum that contains it. There would be a constant tendency for the oil to reach a higher level at the expense of the water. It ascends through all the substance of the rock until it reaches the impervious roof, where it is gradually concentrated. On the same principle, the separation of the gas from the oil is effected.

Some of the points that have been made under this head may be briefly restated, as follows:

1. Clay is largely connected with the primary accumulation of petroleum. The natural affinity that it has for substances of this class would lead to its combination with them wherever found. The great shale formation of eastern Ohio, New York and Pennsylvania, is the main source of the petroleum and gas of these regions. Clay does its work in this regard by reason of its chemical constitution.

2. As clay is the main agent in the primary accumulation of petroleum, sand takes a similar place in its secondary accumulation, or its concentration in valuable stocks. It does this by virtue of its physical character. A sandstone is a porous rock. Such sandstones as are found overlying or imbedded in the great shale formation are sure to become receptacles of oil.

3. Clay has another office in this connection to perform, and this office is dependent on its physical character. The sandstone stratum last described, would become a *receptacle* of oil in any case, but if roofed with a sufficient thickness of clay shale by which its contents could be sealed and preserved, it would become a *reservoir* of oil or gas. All of the stocks of the old fields are held in sandstone or conglomerate reservoirs.

4. Limestone has been found, more clearly in Ohio, perhaps, than elsewhere, to replace sandstone in oil accumulation. All the phenomena of high-pressure stocks of oil and gas have recently been found in the Trenton limestone of northern Ohio, but the presence and office of the shale cover are seen to be the same here as in the other fields. The term limestone in this connection is used with due care and precision. It is limestone, not "oil sand" in the limestone, that contains Findlay gas and Lima oil. Pure limestone is the driller's "oil sand" in these fields.

5. Widely diffused as are oil and gas in the paleozoic rocks

of Ohio and adjacent States, so wide that the distribution of them may, without error, be styled universal, and widely extended as are the series of rocks that afford in their composition and relations the proper conditions for storage, it is still seen that their accumulation in profitable quantity depends on what might be called geological accidents. It is only, or mainly along lines of structural disturbance that the great stocks are found.

SECTION II.—THE GEOLOGICAL SCALE OF OHIO.

No description of the occurrence of petroleum and gas in Ohio can be made fully intelligible unless the geological order and structure of the State are held firmly and distinctly in mind. Unusual interest exists in these subjects at the present time, and knowledge in regard to them is eagerly sought on all sides. The expositions of the geology of Ohio given by Newberry, in Volumes I and II of the reports of the survey are not now available to many who are seeking, for the first time, information on this subject, and, lucid and admirable as his statements are, they do not meet all the questions which the developments of the last few years have raised, and which these same developments have helped us in many cases to answer, at least in part.

A brief and somewhat elementary review of the scale and structure of the State will here be given, in order to meet as fully as possible these new demands for geological information. A few fundamental facts pertaining to the subject will be stated before this review is entered upon.

1. So far as its exposed rock series is concerned, Ohio is built throughout its whole extent of stratified deposits, or in other words, of beds of sand, clay and limestone, in all their various gradations, that were deposited or that grew in water. There are in the Ohio series no igneous nor metamorphic rocks whatever—that is, no rocks that have assumed their present form and condition from a molten state, or, that subsequent to their original formation, have been transformed by heat. The only qualification which this statement needs, pertains to the beds of drift by which a large part of the State is covered. These drift beds contain

bowlders in large amount, that were derived from the igneous and metamorphic rocks that are found around the shores of Lakes Superior and Huron, but these bowlders are recognized by all, even by the least observant, as foreign to the Ohio scale. They are familiarly known as "lost rocks," or "erratics."

If we should descend deep enough below the surface, we should exhaust these stratified deposits and come to the granite foundations of the continent which constitute the surface rocks in parts of Canada, New England and the West, but the drill has never yet hewed its way down to these firm and massive beds within our boundaries.

The rocks that constitute the present surface of Ohio were all formed in water, and none of them have been modified and masked by the action of high temperatures. They remain in substantially the same condition in which they were formed.

2. With the exception of the coal seams and a few beds associated with them and of the drift deposits, all the formations of Ohio grew in the sea. There are no lake or river deposits among them, but by countless and infallible signs they testify to a marine origin. The remnants of life which they contain, often in the greatest abundance, are decisive as to this point.

3. The sea in which, or around which they grew was the former extension of the Gulf of Mexico. When the rocks of Ohio were in process of formation, the warm waters and genial climate of the Gulf extended without interruption, to the borders of the great lakes. All of these rocks had their origin under such conditions.

4. The rocks of Ohio constitute an orderly series. They occur in widespread sheets, the lowermost of which are coextensive with the limits of the State. As we ascend in the scale, the strata constantly occupy smaller areas, but the last series of deposit, viz: those of the Carboniferous period, are still found to cover at least one-fourth of the entire area of the State. Some of these formations can be followed into and across adjacent States, in apparently unbroken continuity.

The edges of the successive deposits in the Ohio series are exposed in innumerable natural selections, so that their true order can generally be determined with certainty and ease.

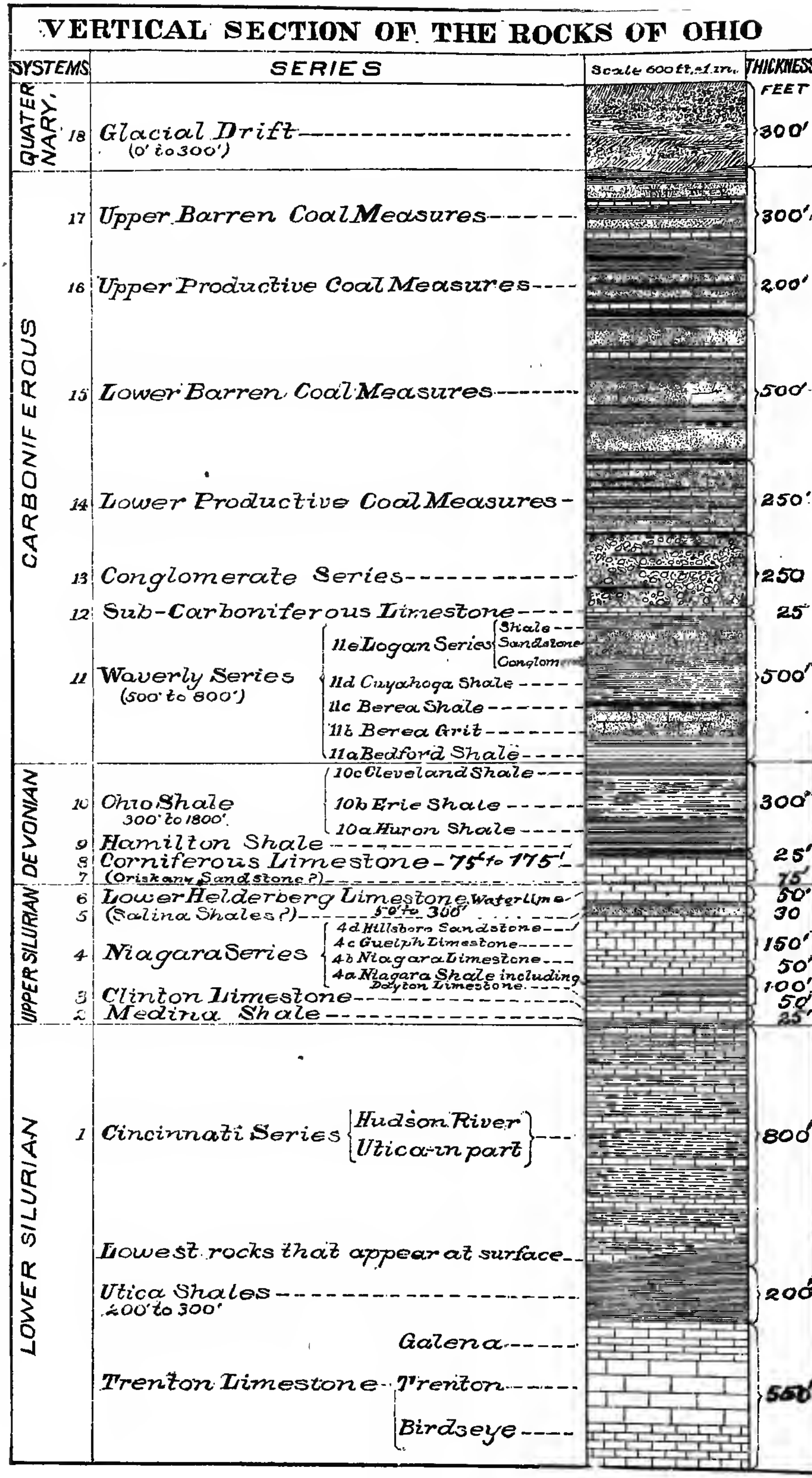
5. For the accumulation and growth of this great series of

deposits, vast periods of time are required. Many millions of years must be used in any rational explanation of their origin and history. All of the stages of this history have practically unlimited amounts of past time upon which to draw. They have all gone forward on so large a scale, so far as time is concerned, that the few thousand years of human history would not make an appreciable factor in any of them. In other words, five thousand years or ten thousand years make too small a period to be counted in the formation of coal, for example, or in the accumulation of petroleum, or in the shaping of the surface of the State through the agencies of erosion.

The geological scale of the State is represented in the following diagram. The order of the series is, of course, fixed and definite, but the thickness assigned to the several elements depend upon the location at which the section is taken. The range is generally indicated, but in any case it will be stated in explicit terms in the description of the several formations that is to follow. Two of the elements named, viz: the Oriskany sandstone and the Salina shales, are marked with an interrogation point. It is an open question whether these epochs are distinctly represented in Ohio.

THE TRENTON LIMESTONE.

Through the revelations of the drill during the last year or two, we have been obliged to add a new formation to the geological series of Ohio. We begin the series now with the Trenton limestone. It is by no means true that we were ignorant of its presence before these drillings were undertaken, and that we have just learned that it underlies the State. The fact that it belongs at the bottom of the Ohio column has been clearly understood since the geological age of our lowest rocks was first determined, and the relations of these lowest rocks to the Trenton have been discussed at length by many students of our geology. But by means of the drill this great formation has suddenly acquired a large practical and economic interest. Though it nowhere rises to the surface within the limits of this State, we now know its chemical composition, its color, its hardness, its porosity, as well as we do the like qualities of limestones that make our surface rocks for thousands of square miles. Its name has become more familiar, and is


VERTICAL SECTION OF THE ROCKS OF OHIO
SYSTEMS
SERIES
Scale 600 ft. = 1 in.
THICKNESS
FEET
QUATERNARY
18 Glacial Drift (0' to 300')
300'
CARBONIFEROUS
17 Upper Barren Coal Measures
300'
16 Upper Productive Coal Measures
200'
15 Lower Barren Coal Measures
500'
14 Lower Productive Coal Measures
250'
13 Conglomerate Series
250
12 Sub-Carboniferous Limestone
25
11 Waverly Series (500' to 800')
11e Logan Series
Shale
Sandstone
Conglom
11d Cuyahoga Shale
11c Berea Shale
11b Berea Grit
11a Bedford Shale
500'
DEVONIAN
10 Ohio Shale 300' to 1800'
10c Cleveland Shale
10b Erie Shale
10a Huron Shale
300'
9 Hamilton Shale
8 Corniferous Limestone - 75' to 175'
25'
7 (Oriskany Sandstone ?)
75'
UPPER SILURIAN
6 Lower Helderberg Limestone Waterlime
50'
5 (Salina Shales ?) 50' to 300'
30
4 Niagara Series
4d Hillsboro Sandstone
4c Guelph Limestone
4b Niagara Limestone
4a Niagara Shale including Dayton Limestone
150'
50'
100'
3 Clinton Limestone
50'
2 Medina Shale
25'
LOWER SILURIAN
1 Cincinnati Series
Hudson River
Utica-in part
800'
Lowest rocks that appear at surface
Utica Shales 200' to 300'
200'
Galena
Trenton Limestone
Trenton
Birdseye
550'

spoken more times in a day by more people than that of any other of these great strata. The mineral wealth in the shape of gas and oil that it is yielding is already of great value, and every day is adding to this value.

The Trenton limestone as it occurs in outcrop in New York, Canada and Wisconsin, has been divided into two or more divisions. At the west, its uppermost beds are called the Galena limestone the lead ore and galena of Illinois or Wisconsin being found in these beds. At the east, its bottom portion is termed the Birdseye limestone, from the occurrence of crystalline grains of calcite through the substance of the rock. This last named phase occurs in Ohio. From the deepest drillings at Findlay, fragments brought up by the pump showed the birdseye feature distinctly. It is, however, the uppermost portion in which the economic interest of the Trenton in Ohio is found.

The drill has gone down through 550 feet of limestone rock in one instance in Ohio, below the oil and gas rock, viz: in the first well at Findlay, and aside from changes of color, and from the occurrence of the crystalline particles just named, no hints of division could be drawn in it. It probably all belongs to this age.

It comes nearest to the surface in the valley of the Ohio, in the south-western corner of the State. It is probably between 200 and 300 feet below low water in the Ohio, or about 200 feet above sea level. It can be followed by the recent borings to the shore of Lake Erie, dipping slowly and quite equably to the northward, its surface at Toledo, for example, being found 800 feet below sea level. To the northward, it rises in the Manitoulin Islands; to the southward from the Ohio River, it rises in the Blue Grass lands of central Kentucky.

It is a magnesian limestone of a fair character throughout most of its extent. It is found somewhat silicious in some of the drillings.

Aside from its probable presence in the deep well at Cleveland, it is confined so far to the western half of Ohio. The drill has never gone down deep enough to find it in the eastern half of the State, but there is no assurance that it is to be found there in any case as a limestone. In the deep trough of the ancient gulf which is now occupied by eastern Ohio and the adjacent parts of Pennsylvania and West Virginia, the limestone of the northern

border and of the other regions named might well enough be replaced by a very different formation. There is no warrant for assuming its universality as a limestone.

THE UTICA SHALE.

In the New York section, from which most of our geological names are derived, the Trenton limestone is directly overlain by a mass of dark, sometimes black shale, which, from its occurrence in good exposures about Utica, has been named from this place. In New York it is about 300 feet thick. It has but few fossils, but fortunately some of them are characteristic — that is, they have never been found in any other formation. It contains quite a notable amount of organic matter, ranging, as has been asserted, from 8 to 17 per cent. This organic matter is apparently of animal, rather than of vegetable origin.

The only part of Ohio where the Utica shale is due as a surface rock is in the south-western corner, but the beds found here that would come in on this horizon are not dark in color, but are calcareous rather than bituminous, and although they contain some of the fossils that are found in the Utica at the east, they also contain many others. Moreover, it is impossible to draw a firm or natural boundary line between the beds that should be Utica shale and those that overlie them.

On this account, most of the geologists who have worked upon this portion of the series, have counted it best to merge the overlying beds with those that are probably of the age of the Utica, in a single formation named the Cincinnati group. These overlying beds are known as the Hudson River series in New York.

But when drilling began in Findlay in 1884, it soon became evident that the New York section could be followed intact and distinct into northern Ohio. There was a mass of dark, nearly black shale, about 300 feet in thickness, immediately overlying the Trenton limestone. The color and position of the deposit were sufficient to determine its age, but better than this, in some of the chips that were brought up, the most thoroughly characteristic fossils of the Utica shale of New York were found. Notable among these was an almost microscopic shell, *Leptobolus insignis*, that is counted by Hall and Whitfield as the best mark

of the formation. It was this determination, indeed, that served to show the real name and place of the oil rock, or in other words, the Utica shale was the first of the new elements to be referred positively and definitely to its place in the general scale.

The Utica shale can be followed as far south as Springfield and Piqua as a dark shale, but it is growing more calcareous and fossiliferous as it is traced southward. In the Ohio valley, as already stated, the boundary between it and the overlying beds becomes indistinct or is obliterated.

1. THE CINCINNATI SERIES.

This series is equivalent, as just shown, to the Hudson River and Utica formations of the general scale. It embraces the lowest rocks that find their way to the surface at any point in the State. It occupies about 4,000 square miles as a surface rock in southwestern Ohio. It consists of interstratified sheets of limestone and fine-grained shale, called clay. Both are light blue or gray in color, as a rule. The limestone and shale alike are charged with fossils in an excellent state of preservation. These beds are famous, in fact, for the large amount and the excellent preservation of the fossils of this period. The limestone and shale occur in varying proportions in different parts of the series. In the upper portion, the limestone is in larger amount than the shale, and the whole mass is sometimes counted limestone rock.

It does not allow the surface water to descend into it, and it is consequently poor in springs and makes dry drilling.

In the northern part of the State, the upper part of this formation is known only by the well records, and by the drillings brought up from below. It is found here to be much less calcareous and much less fossiliferous than in its outcrops at the southward, though both lime and fossils are abundant in it. It is bluish-green in color, and is often known as the green shale. It has a thickness of 500 to 600 feet. It corresponds well with the Hudson River rocks of New York, in all essential particulars. The fossils found in the drillings are, in some cases, identifiable, and when so are found to be characteristic of the formation.

2. THE MEDINA SHALE.

This is another element of the New York scale that could never be positively identified in the Ohio column until the recent explor-

ations in north-western Ohio. It is well characterized by its position, by its color, by its composition, and it may be added, by the absence of fossils. The formation is almost everywhere poor in the traces of life, either animal or vegetable. In coming westward from New York, it has changed somewhat in composition. In New York, it consists largely of shale, but intercalated in the shale at two points, there are found very valuable beds of quarry stone. This sand is mainly lost in the Ohio sections, though in the uppermost beds there are sometimes thin courses. The color of the formation is characteristic, a light red being the prevailing tint. This mark alone would go far to identify it, as we have no red rocks in this part of the scale, except in the Medina and the associated rocks of the Clinton. It is not, however, red rock in all parts of Ohio, and probably where red rock occurs we should refer shales of other colors to the Medina if we had full opportunities for examination. The thickness of the formation as determined by the color, ranges from 30 to 90 feet in northern and central Ohio. In the southern part of the State where its outcrops occur, it is seldom more than 25 feet thick. The red band of these outcrops was long ago referred to this horizon, but its direct continuity with the rocks of the typical section could not be affirmed until the line of borings from southern Ohio to the lake completed the connections.

The Medina contains no red rock in the Lima field, but a belt of "greenish shales, gravel and sand," as described by the drillers in some wells of this region may possibly represent it. The question is, whether this belt belongs to the Medina or to the Clinton, as the latter formation sometimes includes deposits of this character. There are blue shales immediately below, that can well enough represent the Medina in whole or in part. The oil and gas wells of northern Ohio are mainly cased at this point in the scale, no further interruption from water being experienced in descending 800 to 1,000 feet.

3. THE CLINTON SERIES.

This series occupies a well-marked interval, having the Medina shale below it and the Niagara shale for its upper boundary. The only outcrops of the formation are found in south-western Ohio, and here the whole series consists of limestone beds that are very

definitely characterized. In northern Ohio, as the drill has shown, there is a probability that certain shale deposits found above the red Medina may belong to the Clinton age.

The Clinton limestone in its outcrops is a highly crystalline, uneven-bedded, very fossiliferous limestone. It tends to high colors, white, pink, yellow and red being frequent in it, but it is also gray, blue and brown in some of its beds. It takes a good polish and is frequently called a marble. In chemical composition it differs from the limestones with which it is associated, containing from 84 to 98 per cent. of carbonate of lime, and 1 to 12 per cent. of carbonate of magnesia. At a few points in southern Ohio it furnishes the fossil ore for which the formation is famous. In southern Ohio the thickness of the Clinton ranges from 16 to 60 feet.

It is distinctly petroliferous, oil oozing out at numberless points along its line of outcrop, and giving rise to "surface indications" that led, twenty-five years ago, to the expenditure of considerable amounts of money in futile attempts to secure paying wells at this horizon. Its lower boundary in outcrop is a well-marked line of springs.

Under cover at the northward, it has many of the same characteristics. It shows high colors and crystalline structure, but it is more magnesian in composition than in its outcrops. It gives rise to strong sulphur water, and sometimes to highly sulphuretted gas in the Findlay and Bowling Green districts.

Its thickness at the northward seems to be 75 to 100 feet. In the Columbus well it is a little more than 100 feet thick.

The Clinton limestone is terminated at the southward, and apparently in northern Ohio by a very fine-grained clay. The clay is often white in color, and it generally contains fossils. In the vicinity of Dayton, this seam is prolific in life, and has given a half dozen or more species that are new to science. The clay may be named the Clinton clay or marl. It is rarely more than two or three feet in thickness. This Clinton clay seems to be found in its most characteristic form in the wells of northern Ohio, and especially at Findlay and Bowling Green.

4. THE NIAGARA SERIES.

The formation next to be reached in ascending order, is one of the most interesting and important in this part of the column.

It occupies about 3,000 square miles of the surface of the State. It is quite a varied and extensive series, numbering five distinct and well characterized elements, viz:

The Hillsboro sandstone.
The Cedarville or Guelph limestone.
The Springfield or Niagara limestone proper.
The Niagara shale.
The Dayton limestone.

The first of these elements to be reached in ascending the scale is the Dayton limestone. This is a thin, but very valuable member of the group, but is local in its occurrence and need not be described here.

The Niagara shale is a very important member of the series. It has a maximum thickness of 106 feet in Adams county, in outcrop. It grows thinner to the northward. At Yellow Springs it is about thirty feet thick. In the new oil district the driller sometimes fails to report it, and it may at times be wanting, but in all probability a careful record would show it from five to twenty-five feet thick in every well. It is distinctly shown at Columbus, being struck in the new well at 622 feet below the surface, and having a thickness of seventy feet.

It is a water horizon in outcrop and under cover. Salt water, rank with sulphur compounds, is produced from it in northern Ohio.

The Springfield stone, or Niagara limestone proper, is a firm, even-bedded, fairly pure magnesian limestone, with a thickness in outcrop of about fifty feet. It is blue or drab in color, and is largely quarried as a building stone.

The larger part of the Niagara series belongs to the next division, viz: the Guelph or Cedarville division, an interesting and valuable formation on many accounts. It is a wonderfully pure dolomitic or magnesian limestone over large areas, furnishing the best limes of this group that are possible. It is a great storehouse of most interesting fossils, almost all of which occur as internal casts. It has a maximum thickness in outcrop of 150 to 200 feet. It occupies all of the surface of northern Ohio that is assigned to the Niagara. It is generally light-colored, drab or cream in tint, but is sometimes blue.

A mass of clean, sharp sand, thirty feet in thickness, that

occurs in the Niagara series in southern Ohio, is known as the Hillsboro sandstone, and does not need further description here.

At some points in the State the Niagara is highly bituminous, the asphaltic matter being distributed throughout the substance of the limestone.

5. THE SALINA SHALES.

This is an element of small value at most in the Ohio scale. There is a question whether any distinct boundaries can be assigned to beds of this age. The last named group may have been formed in part in the Salina epoch.

6. THE WATERLIME OR LOWER HELDERBERG LIMESTONE.

The great sheet of thin and even-bedded light brown or drab, or sometimes blue magnesian limestones, poor in fossils, but rich in bituminous compounds as petroleum and asphalt, that is found directly overlying the Niagara series, and that constitutes the surface rock for not less than 4,000 square miles of the State, is known in geology by the ill-chosen and misleading designation, the waterlime. Part of the series, no doubt, belongs to the lower Helderberg, which by some geologists is made distinct from the waterlime, and by some is made to include it. This formation is seen in its best development at Greenfield, Highland county, but at Put-in-Bay, at Lima, at Bluffton, at Carey, at Urbana, and at scores of other points, important sections of it are found. It has a maximum thickness of 300 feet, as is shown by the record of the new Columbus well. In sections along its outcrop it ranges from 20 to 100 feet, but the maximum is much nearer the average than the last named figures.

The Niagara limestone and the waterlime together occupy a large area in northern Ohio, but it is misleading to represent their areas by distinct colors or other symbols on a map. They are sometimes, as at Genoa, both worked in adjoining quarries. The same farm frequently contains several patches of waterlime in a thin cover over the Niagara, and thus throughout the district. More than this, in these drift-covered regions, it is impossible to give a valid judgment as to which rock will be found, in many instances. The separation of them when worked in quarries is very easily and definitely made. The bedding, the color, the bituminous products

and the fossils are distinguishing marks. In composition they are often identical.

7. THE ORISKANY SANDSTONE.

This is an uncertain element in the Ohio scale. A bed or beds of sharp, pure sand, intercalated in the Corniferous limestones, have been designated the Oriskany. There are comparatively few points where this sandstone occurs. Its place in the scale is certainly open to question.

8. THE CORNIFEROUS LIMESTONE.

This is the last of the great series of limestone formations of which the western half of the State is composed. It has two main areas, a belt leading down from Kelly's Island to Pickaway county, and another belt extending across Paulding, Henry and Lucas counties, in north-western Ohio. A third area occurs in Logan county, underlying the highest land of the State.

In composition it ranges from 65 per cent. of carbonate of lime to 95 per cent. The carbonate of magnesia ranges from nothing to 35 per cent. It is, on the whole, the purest carbonate of lime that we find on the large scale in the State. It contains many flint nodules, distributed often in regular courses through the rock. The thickest section of it reported in Ohio is 164 feet, at Sylvania, Lucas county. It seems, under cover, to hold about the same measure, but an anomalous section from the Cleveland well may require this measure to be nearly doubled. In its southern outcrops it is not found more than 100 feet thick.

It is generally light colored, often nearly white. It is even in its bedding and sometimes massive, and yields valuable building stone and lime of high character. Like the waterlime, it carries a small amount of free petroleum, as is shown by the odor of fresh fractures.

The fossils of the formatian are exceedingly interesting and abundant.

9. THE HAMILTON SHALE.

This is a formation of rather uncertain character, and quite local in its development. But few feet would be assigned to it in any series. It is generally blue, somewhat calcareous shale, in

some places highly fossiliferous, and at other points almost or entirely destitute of fossils. It is probably the Olentangy shale of Winchell.

10. THE OHIO SHALE.

The great shale formation that we next reach in ascending the geological column of Ohio, is of universal importance in connection with the subjects of petroleum and natural gas. It is undoubtedly the ultimate source of the supply of these substances for almost all of eastern Ohio and Pennsylvania, and New York as well. The direct source is found in the sandstones that cover or are imbedded in this shale formation.

This formation consists of black shales and blue or gray shales, interstratified without any definite order. There are patches of black shale, for example, found at one locality, that do not occur in another section. Some of the bands are quite persistent, it is true, but no section can be furnished that will give even an approximation to the order that will be revealed in a new locality in the central part of the field. The old order that was laid down, of black shales at the top of the column (Cleveland), blue shales in the middle (Erie), and black shales again at the bottom of the series (Huron), is not close enough to the facts as they are now known to be of any service. It is misleading rather than helpful. There are points where just such a section is found, but there is a vastly greater number of localities where no such order prevails. Near the bottom of the shales, black beds, however, always occur. Greenish-blue shales are always found interbedded with darker seams in the middle of the section. On the western outcrop the top and bottom as well are always black. In fact, there is very little but black shale in the section here. Sometimes, however, there is a great uniformity for hundreds of feet.

The thickness of the series depends upon where it is measured. At one point in Highland county, the entire interval between the waterlime and the Berea grit is but 250 feet. Along the western margin or outcrop of the main formation, there are generally 300 feet or more. In the interior, on certain lines, there is a very rapid increase. At Cleveland the system is about 1,300 feet thick. At Canal Dover the drill went down through 1,800 feet without exhausting the series.

There are but few sandy seams scattered through this great

series in Ohio. It is fairly homogeneous in character aside from the organic matter which it contains. It is in this formation to the eastward that the great oil sands of Pennsylvania and New York are buried, but these are wanting for the most part in Ohio. In the extreme southern border of the State, one or more small beds have been recently found that, perhaps, belong at the same general level with the Venango oil sands.

The darkest portions of the series are quite rich in bituminous products as petroleum and gas, and also in organic matter. The latter sometimes rises to ten per cent. of the rock. It can be expelled by burning the shales, or it can be distilled into kerosene and gas. The petroleum that exists as such in the rock is in comparatively small amount, but its aggregate is large. In some of these black beds more than one-fifth of one per cent. has recently been found of heavy oil. The bituminous compounds are not, however, confined to the black bands of shale. The lighter bands often contain a notable proportion.

Along the outcrops of the formation from Pennsylvania, through Ohio and Kentucky into Tennessee, gas and oil are constantly escaping. Wells drilled into the shale almost always secure at least a small flow of gas, at least where there are several hundred feet of shale.

II. THE WAVERLY SERIES.

This important group occupies about 7,000 miles of the surface of the State. It is more complex in structure than any of the series that have thus far been passed in review. In it the first persistent sandstones of the Ohio scale occur. These sandstones are of great account in the accumulation of oil and gas, which ascend into them from the shale formation which they cover. The Waverly series embrace the following elements, which were mainly first distinctly recognized and named by Newberry:

Logan Series. { Shale. Sandstone. Conglomerate.

Cuyahoga shale.
Berea shale.
Berea grit.
Bedford shale.

In eastern Ohio the section is shortest, the entire thickness being sometimes reduced to 300 feet. In central Ohio, a maximum of 800 feet is attained.

The elements are, on the whole, wonderfully persistent and uniform in character. Not even the limestones of our scale can be followed as far with so little change of mineral constitution as the shales and sandstones of the Waverly.

The Bedford shale is an excellent mark by reason of the red color which it very often shows. Where not red shale, it is blue or light-colored, and along its outcrops where it rests upon the dark beds of the Ohio shale, the contrast is well marked. It is 50 to 75 feet in thickness. In northern Ohio, it holds locally some beds of excellent flagging and building stone.

The Berea grit which we next reach, is one of the best known and most valuable strata of the State. In its outcrops, it furnishes our best building stones and grindstones. Under cover, it becomes a reservoir of gas and oil on the large scale.

It ranges from 5 to 100 feet in thickness, but it seldom passes the limit of 50 feet, while it falls below 20 feet for thousands of square miles. The drill is revealing its persistency and continuity to a surprising degree.

Its outcrop constitutes one of the best marked horizons of the State. Being the first persistent sandstone in our scale, and being roofed and underlain alike with shale, it stands out with terrace-like distinctness through much of its western border.

The Berea shale which covers it is a mass of dark, generally black shale, 20 to 40 feet in thickness, rich in petroleum and organic matter, and abounding also in fossils of great interest. Fish remains of unusual character occur in it abundantly in places.

The black Berea shale, making the roof of the Berea grit, helps to mark and determine its place. Taken in conjunction with the underlying Bedford, it forms a series of unique character. A sandstone, the first to be found in ascending, the last to be left in descending the column of the State, this sandstone under cover always a reservoir of salt water, oil and gas, one or all, with a persistent coal-black roof, and underlain with a red or chocolate-colored band for its floor, all this gives to the horizon a picturesque distinctness.

One other surprising element must be added, whether to the

Berea grit or to the Berea shale, may be a matter of question. The last named element seems to have the best claim. In the quarries at Berea, at the bottom of the highly fossiliferous Berea shale and thus immediately overlying the quarry stone, a hard, sulphurous layer occurs, black in color but sandy in composition. It is, however, rich in fossils, containing some fish remains of great size and of new types. This last fact, its fossiliferous character, namely, allies it to the Berea shale rather than to the Berea grit. This crust is but a few inches in thickness, and might well be taken, by one who should study it at Berea, only as an altogether local exhibition. But surprising as it may seem, it is coextensive with the Berea grit. The driller at Macksburg, or in the Ohio valley is as familiar with this hard "cap," as is the quarryman or collector of fossils at Berea. Immediately below the cap in the oil-producing field, the great supplies of stored gas and oil are found.

The Cuyahoga shale that follows, makes the cover of the oil sand in the large way. It is a light colored, close-grained, compact shale, quite impervious to water, and thus seals in the contents of the sandstone securely. It is 200 to 500 feet in thickness. It carries frequent layers of sandstone or freestone, some of which are of great value as building stones. The famous City Ledge, of Adams and Scioto counties, belongs near the base of the Cuyahoga. The Portsmouth stone and the Waverly brown stone are somewhat higher in the series. The Warren flaggings, of Trumbull county, belong also near the base of the Cuyahoga.

The Logan series is the most anomalous and perplexing of all the divisions of the Waverly, by reason of its inconstancy. It was omitted from the earlier sections, but it proves to be one of the most conspicuous and important parts of the series. The most noticeable element of the Logan group is the Waverly conglomerate, a mass of sandstone and pebble rock, with difficulty, if at all, to be distinguished by physical characters from the coal measure conglomerate. In fact, in all of the earliest reports on Ohio geology, it was unhesitatingly taken for the last named stratum.

It has a maximum thickness of 200 feet, and holds steadily under cover as a great sand rock, generally full of salt water and therefore known in many oil fields as the salt water sand. It sometimes contains high-pressure oil and gas.

It is often overlain by a heavy mass of shales 100 to 200 feet in thickness, which are charged with Waverly fossils. At other points it comes very close to the base of the coal measure rocks and could easily be counted in with them.

12. THE SUBCARBONIFEROUS LIMESTONE.

This is not an important element in Ohio geology so far as its outcrops are concerned. These are few and far between. They occur in Scioto county sparingly, in connection with the flint fireclay deposits, in Jackson county as the Hamilton township limestone, in Perry county as the Maxville limestone, and in Muskingum county as the Newtonville limestone. But the formation is acquiring new importance under cover. Drillings at many points in the Ohio valley show it to have a thickness of 50 or 60 feet, and by its occurrence it helps to determine the order of the strata that are penetrated.

13. THE CONGLOMERATE COAL MEASURES.

The base of the coal measures is marked by a great accumulation of coarse sand rock and pebble rock at many points. There are three widespread and fairly persistent conglomerate strata, known as the Sharon conglomerate, the Massillon sandstone, and the Homewood sandstone. In the intervals between these heavy ledges, coal seams, coal measure limestones and thin seams of iron ore sometimes lie embedded. In Ohio, this series of coals has considerable importance, but elsewhere the great sandstones for the most part monopolize the scale and are there known by a single name, viz: the conglomerate. In Ohio, also, two or more of these strata are often welded together into one mass. The interval between this conglomerate and the Waverly conglomerate is uncertain, except where the last described element, viz: subcarboniferous limestone, is interposed, but generally a mass of shales of greater or less thickness occupies the space. Sometimes, however, the two masses are probably found so close together that they are taken by the driller for one.

Shales occur throughout the coal measures in such amount that they furnish suitable cover to most of the great sandstones, making them petroleum reservoirs when other conditions are favorable.

The conglomerate sandstones above named, one or more,

frequently become sources of salt water, oil and gas, though no large stocks of the latter substances are derived from this horizon in Ohio.

14. THE LOWER PRODUCTIVE COAL MEASURES.

The strata of this series have an average thickness of about 500 feet, and include several considerable sandstones, the most prominent of which are the Freeport, lower and upper, and the Kittanning. The Upper Freeport sandstone is thought to become petroliferous at a few points, as in the Macksburg field, but the determination is not certain.

15. THE LOWER BARREN COAL MEASURES.

In this series, two very important sandstones occur, viz: the Upper and Lower Mahoning. The Upper is called by the Pennsylvania geologists the Buffalo sandstone. It has a conspicuous place in the Ohio coal measure scale, lying, as it does, between the two main landmarks and guides of the barren measures, viz: the Cambridge and the Ames limestones. The upper of these sandstones is the source of the shallow oil of Morgan and Athens counties. It is also found productive in Washington county, in the Cow Run field and elsewhere.

16 AND 17. THE UPPER PRODUCTIVE AND BARREN MEASURES.

These groups require no description at this point. They occupy comparatively small areas in south-eastern Ohio. They have a combined thickness of about 500 feet, but they are not known to furnish any important stocks of oil or gas.

18. THE GLACIAL DRIFT.

The drift beds of Ohio cover three-fourths of its surface with deposits that rise as high as 445 feet in thickness, in exceptional instances. This extraordinary measure has recently been attained in the drilling for gas at St. Paris, Champaign county. These drift-deposits are uncertain in composition, from point to point, and nothing approximating a general section can be given. The fact that beds of a certain character were found at one locality gives no warrant for expecting a like series at another, a half mile away. These drift beds are a great source of risk and often of loss

to the contractor. He may be obliged to spend weeks or months in getting through 50 or 100 feet of quicksand or bowlder clay. Sometimes a bowlder is struck when 100 or 200 feet of drive pipe are already in the well and the work may then be necessarily abandoned. It is the part of common prudence in sinking a trial well, for both the company and the contractor to locate as near to outcropping rock as possible. The sooner the drill has passed the danger of quicksand and bowlders, the better.

The geological scale of the State has now been briefly reviewed. With the aid of the geological map appended, the distribution and areas of these several formations (the separate divisions of the coal measures excepted), can be made out. No attempt is made in this map to distinguish the waterlime from the Niagara and Clinton limestones. The latter is found only on the southern margin of the Upper Silurian. In northern Ohio, it is impossible to indicate with any approach to accuracy the relative areas of the waterlime and Niagara limestone, as has been already shown.

SECTION III.—THE GEOLOGICAL STRUCTURE OF OHIO.

A few words are needed at this point upon the *structure* of the State. Under this head is included an account of the dip of the strata, of all axes, arches, folds or anticlinals that occur in its rock formations, and also of all faults or interruptions in continuity of its various elements.

THE CINCINNATI ANTICLINAL.

The dominant feature in the earlier history of Ohio is a low fold, so-called, that entered the State in its south-western corner, from Kentucky, and that gradually advanced across it to Lake Erie and the Michigan border.

It is called an axis or anticlinal, but there is nothing in it that answers to the common idea of such a structure. It is not a sharp ridge, or in fact any kind of a ridge, but as far as can now be seen, it consists of a flat tract, 30 or more miles in breadth, with very little dip, if any, in an east and west direction, but descending to

the northward at the rate of 3 to 5 feet to the mile, with great steadiness and uniformity. When it comes within 20 or 30 miles of Lake Erie, it makes a sharper descent, falling at the rate of 15 or 20 feet to the mile, for that distance. On the eastern side of this tract or axis, the strata begin a uniform descent at the rate of 15 to 25 feet to the mile, in a direction always south of east. The usual direction lies between S. 60 E., and S. 75 E. This rate and this direction hold far within the coal field, giving way to a more southerly direction and being sometimes transformed into a simple southward dip in north-eastern Ohio.

The limit of the western slope has not been traced throughout. Probably there is no definite and continuous boundary, but within the area of the original uplift, there are many inequalities in the level of the Trenton Limestone. A line of sharp descent to the westward passes through the town of Findlay, and is connected with the great production of gas at that point. Another such line passes through Putnam and Wood counties, but on the other hand, the surface of the Trenton limestone is approximately at the same level at Van Wert, Lima and Upper Sandusky — or along an east and west line 60 to 70 miles in length. Facts are rapidly accumulating which will give a sufficient basis for generalization upon this point.

There seems no reason to believe, at the present time, that there is within this entire area any facts of structure corresponding to the general idea of an axis, viz: a tract of narrow breadth, a mile or two at most, extending for many miles or scores of miles, with rapid descents on either side.

It appears that the elevated tract now under consideration received its present structural features at an early day. The Trenton limestone must have been affected by the movements which have disposed it in its present conditions before the great mass of soft rocks by which it is now covered, were deposited upon it. At all events, there is a smaller measure for these shales by 200 feet in the central region, than there is immediately to the eastward. In other words, there is an arch in the underlying Trenton, revealed by the drillers, of which no hint whatever could be obtained by the surface exposures.

It is only on these elevated portions of the Trenton limestone that oil and gas have so far been found. In Findlay (upper level),

and in Bowling Green, its upper surface has been found to be 300 to 400 feet below sea level. In the lower level at Findlay, it falls as low as 480 feet below sea level. At Lima it is about 400 feet below. At Carey, where small gas wells have been struck in the Trenton, its surface is 510 feet below sea level. Nothing of real value has thus far been found in it where the top of the Trenton descends below these figures. Of course, good wells may be found at any time, which will overthrow the value of this deduction, but to the present date all the facts brought in have confirmed it.

OTHER ARCHES AND IRREGULARITIES OF STRATA.

In eastern Ohio there are a few low anticlinals that traverse the rocks, affecting them equally from the top to the bottom of the scale. Some of them come in from western Pennsylvania, and gradually die out here. Others originate in Ohio and run their whole course, never a long or marked one, in the State.

East Liverpool and its neighborhood are traversed by one of these folds. Steubenville and the region below it on the river also show similar disturbance. In both cases the disturbance is slight and ineffectual as a means of accumulating gas or oil on the large scale. The fatal salt water dropsy attacks and destroys the wells that are drilled here. There is a slight fold near Salisbury, on Yellow Creek. Cambridge is at the center of the most conspicuous uplift in the eastern part of the State. It is quite likely that it extends to the south-westward through Morgan county. There are lines of arrested dip in the vicinity of Gaysport and McConnelsville that may be, one or other, connected with this disturbance. Mineral Point, Tuscarawas county, is a region of disturbed stratification, but no axis has been traced through it.

Sinking Springs, Highland county, and a few square miles around it, contain by far the most striking effects of disturbance shown in Ohio. There are actual faults here of 300 feet or more in amount.

There are also lines of fracture in the shales of northern Ohio that may constitute minor axes. In the valley of the Rocky River, near Berea, good gas wells have been found on these lines of uplift.

There is much more to be learned of north-western Ohio than

has been believed hitherto. A most interesting field of study is opening here, in which fractures and dips, undreamed of in these drift-covered plains, are revealed to us, exceeding in amount and geological importance anything that we know elsewhere in the State. The shore of Lake Erie west of Cleveland, also has many points in this connection deserving of careful investigation and measurement. In the vicinity of Kalida, Putnam county, there is a well-marked structural disturbance. A sharp, but probably superficial anticlinal cuts the rocks for a considerable distance.

A peculiar form of movement has been experienced at several points in south-eastern Ohio, which is found to ally itself with petroleum and gas supply in a most important way. It may be styled the terrace structure. It seems to replace the arch, or rather to constitute the later stages of the arch as it is dying out. There is an arrest of dip in a series that has been found sloping regularly in a given direction. For a mile, more or less, the beds run level, or nearly so, and then resume their equable descent. This may be styled the suppressed arch or anticlinal. It was first pointed out by Mr. F. W. Minshall, a sagacious observer and an experienced oil operator, in the Macksburg field. Careful leveling of this field has brought out this structure very clearly. All the oil production of Macksburg comes from the level portion of the rocks or the terrace, a half dozen horizons proving productive within this area, and not outside of it. Gas is found on the upper edge of the oil field where the rocks begin to rise, and salt water is now being reported in the wells on the descending slope of the oil sands.

The determination of all these structural features in Ohio is the more difficult by reason of their apparent insignificance. It is not as in Pennsylvania, where he who runs may read the record of rise and fall, of arch and trough, but here only careful measurements and close observations will detect the departures from normal rates. On the whole, Ohio is a wonderfully regular 40,000 square mile of the earth's crust. In composition and in structure alike, it follows the simplest and the fewest laws that are possible.

PRESENT PRODUCTION OF PETROLEUM AND NATURAL GAS IN OHIO.

Under this head, a few of the leading facts will be given as to the oil and gas fields of the State at the present time.

There are two main horizons of oil and gas now known in the geological column of Ohio, viz:

The Berea grit.

The Trenton limestone.

There are numerous other horizons at which oil and gas, one or both, are occasionally found, but generally in small quantity. These extra horizons are mainly the conglomerate and coal measure sandstones, but one valuable source of gas remains to be added to them, viz: the Ohio shale, along its lines of outcrop. These several horizons will be briefly discussed.

SECTION IV.—THE TRENTON LIMESTONE AS A SOURCE OF PETROLEUM AND HIGH-PRESSURE GAS.

The Trenton Limestone is one of the most widely extended strata of the North American continent. It stretches from the islands north of Hudson's Bay, to Alabama, and from Quebec to Minnesota. It has thousands of outcrops within these wide boundaries. It is known to be bituminous in New York; in Canada it yields a little oil; in Kentucky and Tennessee also, it has been credited with oil and gas production, but it was a geological surprise when it was found to be a great storehouse of fossil power underneath the flat country of northern Ohio. It had already been tapped at various points in the State, and had given no sign of such contents. The drill had reached it at Eaton, at Cincinnati in numerous wells, at Columbus, and at a few other points, and in none of them had it given rise to even the suspicion of being heavily charged with oil or gas. The discovery of this new horizon is certainly one of the most remarkable and important discoveries in the geology of the State. The rock is already yielding

many million feet of gas per day, of enormous value as a source of power. It is also producing 1,000 to 1,500 bbls. of oil per day, and the development is going forward with great rapidity, and with all of the excitement that everywhere attends such exploitation. At least a half million dollars will have been spent in drilling wells in the new field by the close of the present year, according to present indications. Tankage on the large scale and pipe lines are being introduced into the chief centers of production, and in short, all the familiar experiences in the opening of a new oil-field are going forward here, with a lower Silurian limestone that lies a thousand feet and more below the surface, and the nearest outcrops of which are 500 miles distant, as the base of operations. All this is a complete geological surprise. The practical driller has a maxim to the effect that "geology never filled a tank." Certainly geology takes no credit for the discovery of Trenton limestone oil and gas in north-western Ohio.

THE FINDLAY FIELD.

The credit of the discovery of high-pressure gas in the Trenton limestone belongs largely to one man, Dr. Charles Oesterlin, an old and highly respected citizen of Findlay. Natural gas has been known in Findlay since the country was first settled. In digging wells, cisterns and sewers, in springs and rock crevices, inflammable gas has been constantly found during the last fifty years. It has been utilized here in the small way for more than forty years. Prof. Winchell, in his report upon the geology of the county in 1872, made mention of the interesting fact that Mr. Jacob Carr had, for a number of years, lighted his house on Main street with gas collected from wells on his premises. The gas was introduced into this house by Daniel Foster in 1838, and has been burning ever since. Other facts bearing on the gas supply were given by Professor Winchell. The composition of the gas had been determined for Mr. Carr by Dr. Chilton, of New York, who pronounced it light carbureted hydrogen and derived from petroleum. The first statement gave the result of an approximate analysis, and the second was a sagacious inference.

The sulphurous compounds of the gas were especially observable. A small percentage of sulphuretted hydrogen goes a good way in advertising its presence. This gas was absorbed by the

water of wells and springs, which was made in many cases unfit, or at least unpleasant for use in this way.

Explosions frequently occurred in wells, sewers and other excavations, by reason of the accumulation of the gas. These facts were familiar to everyone, and the presence of the gas was looked upon as an evil to be endured, or as a nuisance that could not easily be abated.

Dr. Oesterlin seems to have been the only one who saw clearly that there was a source of light and heat in it that could possibly be utilized in a large way. He urged, many years ago, the formation of a company to drill for gas, and when the Geological Survey of the State was organized in 1869, he brought the subject before a member of the corps, but the time had not come for the recognition of this form of power. The experience of Pittsburgh was needed to complete the demonstration that a new source of light and heat is available to at least a few favored districts. The interest in the new fuel that was gradually invading Ohio, made it possible, early in 1884, after several ineffectual attempts, to organize a company to drill for natural gas at Findlay. In this organization, Mr. Charles J. Eckels stood next to Dr. Oesterlin in recognizing and urging the possibilities of Findlay. It is quite certain that drilling would have been undertaken here sooner or later if this organization had not been formed, but in point of fact, it fell to the Findlay Natural Gas Company to make the demonstration by the drill, in November, 1884, that high-pressure gas existed in a firm but porous limestone rock, that was reached at 1,100 feet below the surface of the town. This discovery is the most important, in a practical point of view, that has ever been made in the geology of Ohio.

The drilling was conducted by Brownyar & Martin, of Bradford, Pa., and the immediate supervision of the work was undertaken by Mr. W. M. Martin, the junior member of the firm. To Mr. Martin's intelligent interest in his work from that time to the present, and for the various well-records and important facts that he has furnished, the Geological Survey is under great obligation. The Natural Gas Company in their contract, made the requirement that the well-record should be carefully kept, and that samples should be saved of all changes in the rocks. All this was done, and now Mr. Eckels, already named as a member of the company,

took upon himself to collect a full set of samples of drillings, and his work was done with care and completeness.

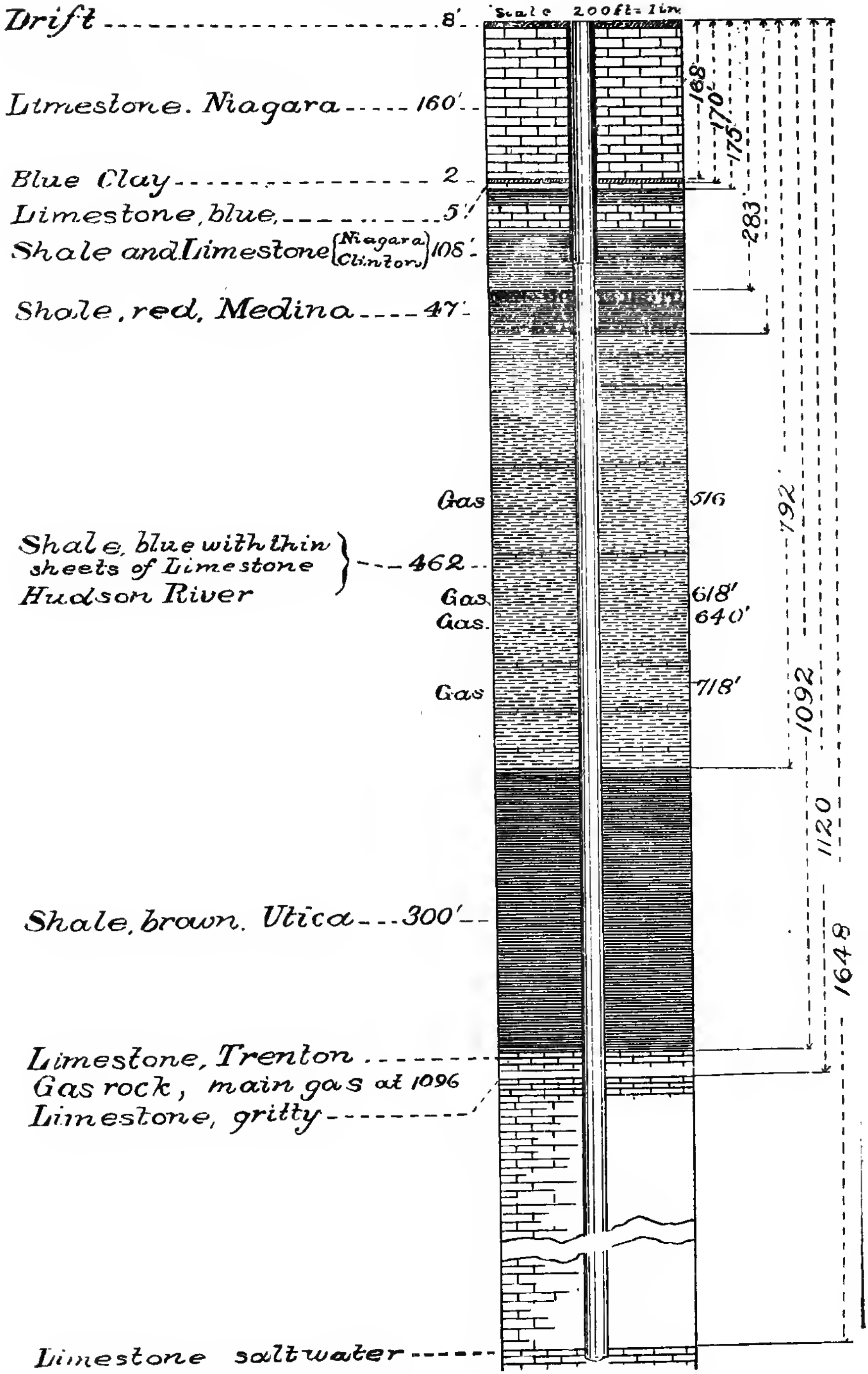
These drillings of the first well were turned over to the service of the survey, and the record, though unexpected, proved to be surprisingly clear and unambiguous. It was, in fact, the type section of the interval traversed from the New York scale that was here found. The Cincinnati group, of southern Ohio, which has already been shown to be composed of the Hudson River and Utica formations, so blended that the line cannot be safely drawn between them, and that moreover, has in southern Ohio a large and frequently a predominant percentage of limestone, was here found to have lost the latter element mainly, and to be very distinctly differentiated into the typical and representative sections of New York. In other words, there was found here the Hudson River shales of New York, with characteristic color, composition, fossils and thickness, and below them, the Utica shale, in normal section in all respects. The solid limestone underlying the Utica shale had no uncertain place in the column. It could be nothing else but the Trenton limestone.

Further than this, the red shale of the Medina period, one of the distinct and easily recognized landmarks of this portion of the scale, was shown here with a thickness of 50 feet, overlying the Hudson River shale. Above this, were the Clinton shale and limestone, the latter in high colors as in the outcrops to the southward, then the Niagara shale, or at least a few feet of the characteristic fine-grained clay that has been named the Clinton clay, at its very base, and above this, the Niagara limestone, to the surface upon which or near which, the drill began its descent. All this was highly satisfactory, and by means of this well-determined section, it became easy to follow the work that was so eagerly taken up on all sides. and when the point of beginning was known, to predict in a general way the section to be found.

This first Findlay section is represented in the diagram that is found on the succeeding page.

The supply of gas obtained from the surface of the Trenton limestone in the first well though vigorous, was not all that was counted possible, and in default of previous experience, it was determined to go deeper in search of a more abundant flow. The drill finally rested at 1648 feet below the surface, still in limestone

SECTION AT FINDLAY
WELL No1



rock, but no accessions of gas were made in this long and expensive descent. The 552 feet of limestone, unbroken except by occasional slight changes in composition that was passed through in this last descent, probably all belongs to the Trenton age. The Birdseye mark came distinctly to view in the drillings from 1500 feet or thereabouts.

Salt water was struck at a number of horizons, but the most vigorous current came from the bottom. The well was finally plugged 100 or more feet below the gas horizon, and the salt water was mainly held back. A little petroleum came from the gas rock as it was drilled deeper. It was a black, heavy, fetid oil with a gravity of about 35° B.

As was to be expected from the surface indications in and about Findlay, gas was found all the way down the well. Notable supplies were obtained at 516, 618, 640 and 718 feet, all in the Hudson River shale, and apparently under limestone caps. The last horizon (700 feet), is a permanent and important one in several wells, and in various parts of the new field. The gas of the Hudson River shales is probably derived from the underlying Utica shale that contains a small percentage of petroleum in addition to a considerable percentage of organic matter. It often occurs in "blowers" or pockets that show high-pressure for a few hours and then disappear altogether. The shale gas generally contains a larger percentage of sulphur compounds than the main supply, but there is a point of view in which this rank odor of both is an advantage. Its presence is at once detected whenever leaks in pipes occur.

The main gas of the first well came with force enough to run an engine when turned into it instead of steam. When lighted from a stand pipe it was visible at night on all sides at a distance of 10 or 15 miles. The flame that shot up from it bore witness to a fact of immense importance to Findlay and to other districts of north-western Ohio. Curiosity at first bore sway, but this presently was re-enforced by a more practical interest. Other wells were at once projected, and the gas was soon brought into varied use.

The Findlay Gas Light and Coke Company (artificial gas) saw that its occupation was gone unless it too secured the new light and fuel. A well put down by Mr. W. M. Martin for this company early in 1885 repeated the history of the pioneer well in

almost every particular. The gas was turned at once into the city mains.

The third and fourth wells were begun about the same time, the one by W. K. Marvin & Sons to supply power for their machine shop, and the other by the Findlay Gas Light Company at the Adams Machine Shop, near the Lake Erie & Western Railroad station.

The third well followed in the track of the first two in most particulars, but the Trenton limestone was found a few feet lower. Its yield of gas was shown by the anemometer to be about 80,000 cubic feet per day. The first and second wells, no doubt, yielded more than this, perhaps twice or three times as much.

The fourth well disclosed several new and very important features of the field. The upper limestones were found 350 feet thick, instead of 250, as in the wells already drilled, but underneath, the section was the same as in the first three wells, the Trenton limestone being 1200 feet deep, instead of 1100 feet, as hitherto found. The surface of the ground throughout the town is all at one level, and consequently it was easy to see that there was an abrupt descent of the whole series of rocks traversed by the drill, to the amount of 100 feet in less than half a mile. This rate of dip is the steepest known in the State, but there was nothing whatever in the surface to suggest such a state of facts.

The well was found to yield several times as much gas as the largest already drilled. For the first time, Findlay had secured a fairly vigorous flow of gas. An anemometer measurement taken at this time showed that 1,296,000 cubic feet were escaping each day. With the gas, oil soon began to appear. In the course of two or three months, the well was producing 4 to 5 barrels of oil daily, while the flow of gas was somewhat reduced. Its yield of oil has since largely increased at the further expense of the other element, until now it is valued more as an oil well than as a gas well.

The further development of the field cannot be minutely followed at this time. By the first of April, 1886, there had been drilled 17 wells in and immediately around Findlay. Two of these, the Putnam Street Well and the Firmin Well, were failures. All of the others were productive, eleven yielding dry gas, and four yielding gas and oil. Of the latter group, one is counted

exclusively an oil well, but there is gas enough in it to raise the oil once in 24 hours, the flow averaging 35 bbls. per day. One of the remaining three has been already characterized. The other two yield gas and oil, but one of them produces an inferior quality of oil and is being overrun with salt water to some extent.

Of the eleven wells yielding gas alone, one stands out pre-eminent. The Karg well, which was brought in about January 20th, 1886, is not only by far the most vigorous producer of the Findlay field, but it is, at the same time, the largest gas well of the State, and probably the largest well that was ever known in Ohio. Just how the Karg well should be ranked in comparison with the largest of the Pennsylvania wells, is not certain. The rock pressure of the Findlay field is only about two-thirds of the pressure reported from certain gas fields of Pennsylvania, but no conclusions can be drawn from this fact alone. The *estimated* outflow of the great Pennsylvania wells has been made as high as 30,000,000 cubic feet per day. The *measured* yield of the Karg well is somewhat more than 12,000,000 cubic feet. According to this comparison, it produces less than half the volume of the former, but exact computations cannot be made until the same system of measurement shall be applied to the wells of both sections.

There are two other wells of great force in the field, viz: the Cory well and the Briggs well, both located in North Findlay. The well known as the North Findlay well is also a large producer. The McManness and the Jones wells are also excellent wells.

Of this series careful measurements have been made of the Karg, the Cory, the Briggs and the Jones wells, and their respective outflows from or near the top of the casing per day, are as follows:

Karg Well........................	12,080,000	Cubic	Feet.
Cory Well........................	3,318,000	"	"
Briggs Well......................	2,565,000	"	"
Jones Well.......................	1,159,200	"	"

These measurements were all executed by Professor S. W. Robinson, of the department of Mechanical Engineering in Ohio State University.

A brief summary of the more important facts in respect to Findlay gas and its production will be here given.

1. The composition of Findlay gas as determined by Professor C. C. Howard, of Starling Medical College, Columbus, is as follows:

Marsh gas (light carburetted hydrogen)	92.61
Olefiant gas	0.30
Hydrogen	2.18
Nitrogen	3.61
Oxygen	0.34
Carbonic acid	0.26
Carbonic oxide	0.50
Sulphuretted hydrogen	0.20

In 100 cubic feet there are 125.8 grains of sulphur. Its specific gravity is 57. Hence 1 cubic foot weighs 318.98 grains.

The determinations of composition have been repeated a number of times, and at intervals of several months, and all the facts seem to show a steady and constant composition.

2. The heating power of Findlay gas considerably exceeds that of the present Pittsburgh supply, and notably that of the new Grapeville gas, as thus far reported. The best statements in regard to Pittsburgh gas that have been met are those of Mr. S. A. Ford, chemist of the Edgar Thompson Steel Works. They appeared in the Natural Gas Supplement of the American Manufacturer, April, 1886.

He assumes an average chemical composition of this gas, the fact of its instability being well known. From this average composition, he deduces the heating power of the gas, and finds it to be expressed as 789,694 heat units to 100 liters. If a ton of Connellsville coke is counted worth $2.50, 1,000 cubic feet of Pittsburgh gas is worth $7\frac{8}{100}$ cents, for its heating power.

If a ton of Pittsburgh coal is counted worth $1.20, 1,000 cubic feet of Pittsburgh gas is worth, for its heat units, 3¼ cents. One ton of coal is equal to 36,764 cubic feet of gas.

Professor Howard has applied like calculations to Findlay gas. The results are as follows:

The heat units aggregate to the 100 liters, 878,082.

1,000 cubic feet is worth, coke being $2.50, 9.4 cents.

1,000 cubic feet is worth, Pittsburgh coal being $1.20, 3.9 cts.

One ton of coal is equal to 31,085 cubic feet of gas.

The actual prices of coal and coke are much greater in Findlay than those assumed. 1,000 cubic feet of gas may be counted on the basis of actual prices, as equal to eight cents in coal.

Findlay gas is thus seen to have the advantage at every point.

The heat units of Grapeville gas, according to Mr. John Fulton, aggregate, for 100 liters, 769,766.

Percentages of difference can easily be computed on the basis of the facts here given.

3. The rock pressure of Findlay gas is now about 375 lbs. to the square inch. All wells reach this mark when closed. The large wells reach it in a short time, the Karg well for example, in 1½ minutes; the smaller wells requiring, perhaps, hours. The same line of facts obtains in other gas fields. The futility of estimating the flow of wells from their pressure when closed, is seen from this statement. The large and the small producers meet together on common ground, so far as pressure is concerned. The rock pressure, as nearly as can be learned, has fallen off slightly since the field was opened. In the first wells, 450 lbs. was registered. In none is the limit of 400 lbs. now passed. This fact can occasion no surprise when the immense production of the field in 1886 is considered.

4. The gas and oil production of Findlay are found to be definitely associated with the most marked discordance of structure that is known in the geology of Ohio, except in a single field.

The surface of the town is a part of the great drift plain of this portion of the State, slightly furrowed by the drainage channels that have been drawn across it. How nearly the surface approaches a plain is seen from the following figures: Of 18 wells that are scattered over four to five square miles, the elevations of the casings above tide water range between 771 and 788 feet, and 11 of these well-heads are between 779 and 784 feet above tide. The lowest water of the streams is about 10 feet below the lowest well, or 761 feet above tide. There is probably no point within four to six miles of the town on either side that attains an elevation of 800 feet.

Underneath the surface, this uniformity is lost, and the following facts appear: On the east side of the town, the Trenton limestone is found in a terrace a little more than 300 feet below sea level. In four wells drilled here, the extremes of which are

nearly one mile apart, the upper surface of the limestone is according to the facts reported, 306, 312, 314, 314 feet below the sea.

To the westward from this terrace, there is a sharp descent to another flat floor of Trenton limestone. To the northward also, there is a descent, but not as marked as the former. The highest westward dip is at the rate of 261 feet to the mile, which stands for a slope of about three degrees. It never continues for a mile at this rate, however. It may be added that the limestone floor of the river shows, at a few points in the town, a similar dip, but the exposures are small, and no consideration was heretofore given to them on account of their isolated character. This lower floor of the Trenton is about 475 feet below tide. The main line of strike runs through the town at an angle of N. 14 W.

The wells of the upper terrace all produce dry gas, but in moderate amount. None of them probably exceeds 250,000 cubic feet in a day. As the subterranean slope begins, the wells that are located upon it gather strength and volume. There is but a single apparent exception to this statement. The great wells have all found the Trenton limestone between 330 and 350 feet below sea level, as is seen in the appended table:

	TRENTON LIMESTONE.
Karg	347 below sea level.
Cory	350 " " "
Briggs	330 " " "
North Findlay	342 " " "
McManness	337 " " "
Jones	328 " " "

When the Trenton limestone is found at 400 feet below the sea, oil and gas are both produced, but the oil tends to increase at the expense of the gas. The following wells illustrate this statement:

	TRENTON LIMESTONE.
Adams well	405 below sea level.
Barnd well	403 " " "
Lima road well	394 " " "

Where the Trenton limestone is found more than 450 feet below the sea, the well yields either oil or salt water, though gas

may still be produced in considerable amount. The following wells illustrate this statement:

	TRENTON LIMESTONE.
Putnam street well..............	452 below sea level.
Matthias well, No. 1............	481 " " "
Matthias well, No. 2............	470 " " "
Firmin well, No. 1	470 " " "
Taylor well, No. 1	480 " " "

The Putnam street well was abandoned, but it gave promise of being a small oil-producer. But little gas appeared in it, and it would have been necessary to pump the oil. The Matthias well, No. 1, has already been referred to. It is the well that flows 35 bbls. of oil per day. The Matthias well, No. 2, and the Taylor well are both fairly productive.

5. Findlay gas now supplies the town, from the tea-kettle and street-lamp to the mill, the glass-house, the machine shop and the factory. The Natural Gas Company that drilled the Pioneer well, has been absorbed by the Findlay Gas-light and Coke Company, which, under sagacious and energetic management, has obtained a strong hold upon this new-found source of wealth. Fortune has also been propitious in giving to this company the Karg well.

The rates that the company has established are as follows, in part:

For cooking stoves.........	\$1.00 per month.
" sitting room stoves.....	1.50 " "
" grates	2.00 to \$2.50 per month.
" house lights	15 to 30 cents.
" boilers	from \$150 upwards, per year.
" patent lime kilns (draw kilns)	\$100 per year.

Other parties, individuals and companies have drilled wells also, and the work is still going forward. The latest phase is a proposition to bond the town for \$40,000, to lay pipes and drill wells if necessary, to supply gas at cost. This proposition has been submitted to a popular vote, and has been carried by an overwhelming majority. If carried into operation, it would seem to

threaten the investments of the corporation that has mainly developed the field thus far.

There has been a deplorable waste of the gas during the last year. This was perhaps a necessary consequence of the condition under which the development was going forward. In the spring of 1886, there was for months a daily waste of at least 16,000,000 cubic feet of gas. At the rate of value previously determined, viz: 8 cents to 1,000 cubic feet, this would aggregate a daily loss of $1,280.

These losses should no longer be allowed. The town and the immediate neighborhood give the best promise of containing a vast supply, but it must not be forgotten that it is stored power. There is, in reality, a measurable amount of oil and gas available, and when this is gone, all is gone. No renewal will follow. Public policy would restrict the number of wells. The more openings the more waste, the more rapid the reduction of pressure and the sooner will come the inevitable exhaustion of the fields. When the great flow of the Karg well was unlocked, other wells, a third of a mile away, were seriously influenced by it. The Adams well lost much of its gas, while the production of oil rose in it from five bbls. per day to fifteen or twenty bbls. per day. Even the Karg well itself has begun to throw oil in spray occasionally.

6. The inference that all the enterprising towns of northern Ohio were quick to draw when Findlay first "struck gas," viz: that inasmuch as they were severally underlain by upper Silurian limestone as Findlay is, their chances to obtain the new fuel were as good as Findlay's, is seen to be unfounded. The occurrence of gas and oil in Findlay are associated with an anomalous and most surprising departure from the regularity that in general characterizes the rocks of the State, and the whole question is seen to be a geological one, after all.

THE BOWLING GREEN FIELD.

Bowling Green, the county seat of Wood county, situated twenty-four miles due north of Findlay, was the next town to try the fortune of the drill, beginning the work in February, 1885. The Niagara limestone underlies the town as it does a large part of Findlay. The face of the country, however, slopes gently to the

northward, and the level of the town is from eighty to ninety feet below that of Findlay.

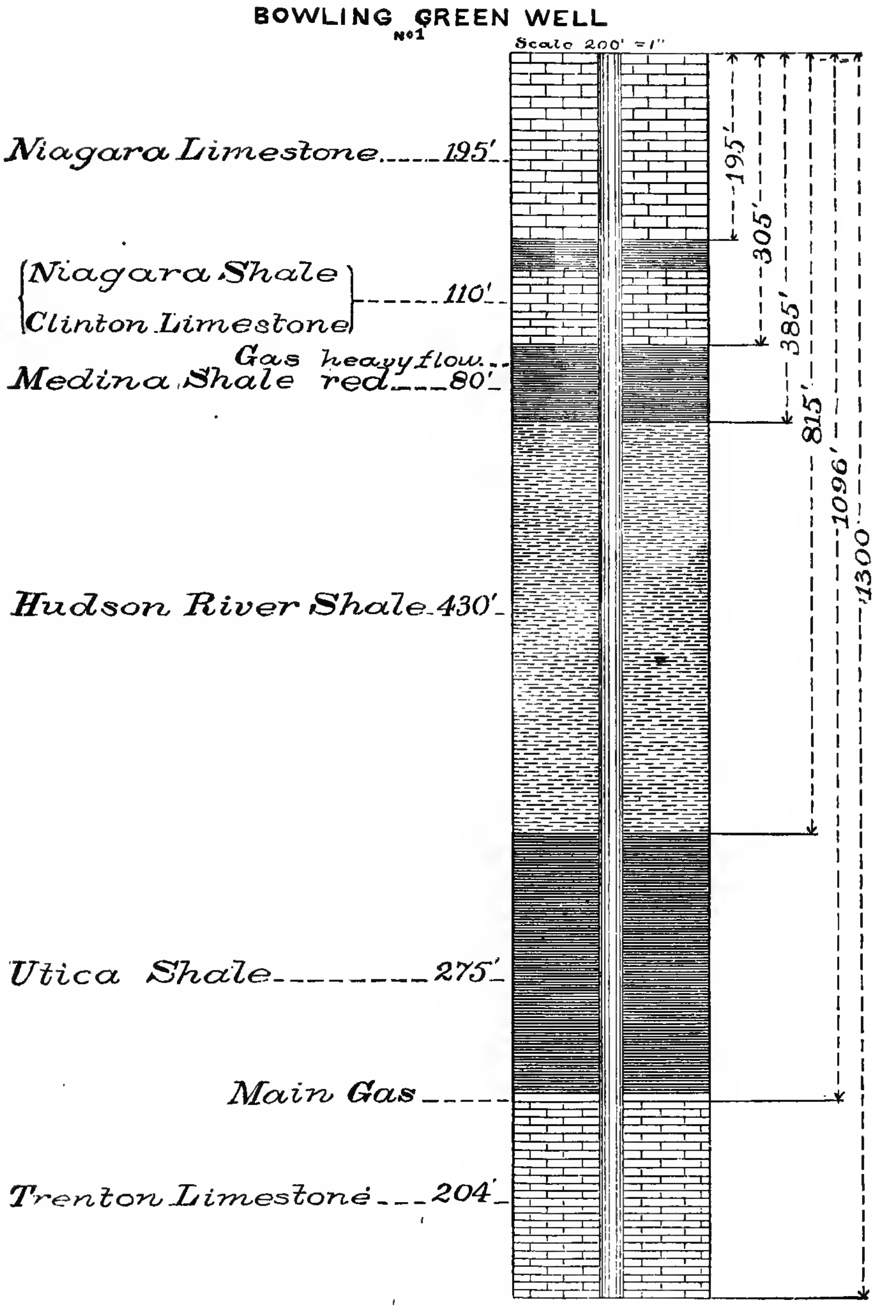
	ABOVE TIDE.
Findlay, Lake Erie & Western R. R. station....	782 feet.
Bowling Green, Toledo & Southern R. R. station.	703 "

The record of the drilling shows an almost exact correspondence with the Findlay records already given. There were 300 feet of upper limestones, interrupted by a thin belt of Niagara shale; there was eighty feet of Medina shale, mainly red in color, about 400 feet of Hudson river shale, about 275 of Utica, and Trenton limestone at 1096 feet, its surface being thus seen to be about 400 feet below sea level. All this is represented in the accompanying diagram. There were vigorous blowers of gas struck as the drill descended, and one in particular, at 330 feet in the Medina shale but probably in a sandy layer, sent out a blaze thirty feet high at first but exhausted itself in about sixty hours.

The Trenton yielded but a very small supply of gas until it was torpedoed. This operation considerably improved its flow. The company that drilled the first well proceeded to sink other wells and to pipe the town so as to furnish gas for general use, and for the burning of lime, but for a year, their stock of gas was short. In March, 1886, one mile south of the town, the first vigorous well was found. This well is comparable with the Findlay wells of the third order. It is doubtless good for more than a million feet per day. Two miles still further south, at Portage, another good supply was found at about the same time.

Bowling Green has been fortunate in not finding good wells inside the town limits. Had such been the case, a well might have gone down on every lot, and the supply would have been frittered away. As it is, the productive field being thus far a mile distant, the company that has drilled the wells and piped the town has virtually a monopoly, which, in such a case, clearly tends to the general good. Gas is furnished at rates about one-third less than the cost of wood or coal, to do the same work, let alone the saving of trouble and expense attending the use of the new fuel. The charges are in part as follows:

House lights............$	20 to 30 cents per month.
Cooking stoves..........	3.00 per month in winter.
Heating stoves..........	3.00 " " " "
Lime burning...........	1 cent per bushel.


BOWLING GREEN WELL
No 1
Scale 200' = 1"
Niagara Limestone 195'
Niagara Shale
Clinton Limestone 110'
Gas heavy flow
Medina Shale red 80'
Hudson River Shale 430'
Utica Shale 275'
Main Gas
Trenton Limestone 204'
195'
305'
385'
815'
1096'
1300'

Four draw kilns of the best pattern have been built here for the last named use, the preliminary experiences have been successfully passed, in the main, and a good quality of magnesian lime is being produced here at a cost that threatens the extinction of this large interest throughout the rest of northern Ohio.

There has not been drilling enough around Bowling Green to show fully what it owes to unusual geological structure, but an exceptionally heavy dip is known to begin upon or near its western boundary. The Trenton limestone descends in going due west from Portage to Weston, a distance of about seven miles, from four hundred feet to nine hundred feet below sea level. Just how this average dip of seventy feet to the mile is distributed does not now appear. It would seem that there is room for remarkable developments in this interval.

THE LIMA OIL FIELD.

Among the centers of production from the new horizon, Lima stands scarcely second in importance. It is rapidly developing into an oil field of considerable proportions, which gives promise thus far of staying quality. The daily production on the first of July, 1886, is estimated to be 1,100 bbls. This production has been held back for some time from the lack of tankage. Now that this lack has been supplied, nitro-glycerine will be brought into requisition on the large scale in wells already drilled, with the certainty of largely augmenting their yield.

Lima was not long behind in following the successful examples of Findlay and Bowling Green. An important railroad center, already actively engaged in many lines of manufacture, full of business energy, and in command of sufficient capital for all promising ventures, it was easy to see that such a flow of natural gas as Findlay had secured would be of immense advantage here. The drill was set to work by the Lima Straw Board Works, an enterprising and successful manufacturing company, in the spring of 1885.

The trial well was located within the grounds of the company and on the bank of the Ottawa River, the top of the casing being about eight hundred and fifty feet above sea level. The section was found to correspond with the Findlay section in all its essential elements.

There were about four hundred feet of the upper limestones,

the Waterlime re-enforcing the Niagara as it does in the western portion of the Findlay field.

The Medina is not a red shale here, but is greenish-blue, like the underlying Hudson River beds, and it is therefore impossible to draw as sharp lines of division as were found in the preceeding wells. The same line of facts holds as to the Utica and Hudson River beds. The lower part of the Hudson River division is darker in color than it is to the eastward. The lowermost beds of the Utica are dark enough to be called black shale. A little gas was found at various horizons in the shale during the drilling.*

The Trenton limestone was struck at 1247 feet, but to the great disappointment of those concerned, no considerable amount of gas was afforded. But as the drill descended a few feet further, oil was found rising in the well. This was an unwelcome discovery, but to save the venture from being an entire failure, and moreover to test the character of the supply, the well was treated thenceforth as an oil well—that is, it was torpedoed, tubed, packed and pumped. In the first six days, two hundred bbls. of oil in connection with some salt water were produced, and the supply then ran low.

The oil was dark, or black oil, heavy and offensive in odor, by reason of the presence of sulphuretted hydrogen. Its gravity after exposure was 36° B. To those acquainted only with oil of the Pennsylvania types, its quality seemed to condemn it.

The Paper Mill well already described was the pioneer well in the Lima field, but by itself it would have made but a feeble impression. It was presently followed by the Citizens' well, which was put down in the summer of 1885, by an association of public-spirited gentlemen who desired to authenticate the field. This purpose it has served in many ways. It was the first well to yield a steady and regular supply of oil, and it was also the oil of this

*A better and more orderly record is furnished by A. C. Reichelderfer, Esq., of the Gas Works Well. It is as follows:

Drift 18 feet.
Limestone.
Sulphur water at 128 feet.
White limestone (Niagara)? begins at 268 feet.
Blue limestone begins at 328 feet.
Limestone with slate streaks continues to 385 feet.

Well cased at 395 feet. No more water.		
Light shale continues to...	880	feet.
Brown shale begins at.....	880	"
Thin black shale at.......	1228	"
Oil rock struck at........	1263	"
Oil-producing "sand".....	1255	"
Salt water rock, slushy....	1260	"

well that was first tested for refining and other uses in the large way. Forty barrels were sent to Pittsburgh refineries in 1885, and the results obtained did much to inspire confidence in the new production. The well has been an expensive one to maintain. It requires steady pumping night and day to hold the salt water in check. By April 20th, 1886, it had yielded about 5,000 barrels of oil. It must always be counted as one of the most important wells of the Lima field, dividing the honors fairly with well No. 1.

The news that Lima had "struck oil," at once attracted the attention of the wakeful men who control the petroleum interests of the country. For nearly a year previous, in spite of multiplying wells and unremitting activity, petroleum production had steadily fallen below consumption, and the possibility of a new oil field became therefore more than usually interesting and important.

To most of the Pennsylvania operators that obtained personal knowledge of the Lima well, there seemed but little promise in it. All the conditions were unusual. A flat country, with every outward indication of being extremely regular and undisturbed, at comparatively small elevation above the sea, and the producing rock a lower Silurian limestone, these facts were enough to discourage many who would have eagerly followed up equal promise in a familiar field.

The representative of one Pennsylvania company, however, Mr. I. E. Dean, who was among the first to visit the new field, had been at one time engaged in oil production in Canada, and was well acquainted with its history and value. Mr. Dean was the first to recognize the possibilities here, and to his intelligent and energetic administration most of the early and much of the later development are due. The Trenton Rock Oil Company, organized by him, has done a great deal in the way of proving the new territory. Much of its earlier work proved unproductive, but it had its value in breaking up crude theories and defining safe limits within which to work.

Up to July 1st, 1886, the Lima field has produced 51,000 bbls. of oil. On April 1st, 1886, there were fourteen wells in operation, with an average production of twenty-four bbls. per day, according to local reports, which are never under the mark. On May 1st there were twenty-two wells with a much larger average, and at the same time there were fifty or more new wells under

contract in the immediate field. On June 21st, the number of producing wells was thirty-four. There were fifteen more being drilled, and there were twenty rigs in the field. On July 1st, there were fifty-seven producing wells, yielding ten to 150 barrels each. Six wells are flowing, and there are fifty-one new derricks in the field.

All of the earlier wells required to be pumped, but the Shade well, No. 1, on the south-east side of the town, completed in February, 1886, proved a flowing well. This was the first of six to date. The use of explosives has converted several of the pumping wells into flowing wells, for a time at least.

Some of the wells flow as soon as the rock is struck. The Hume well flowed about 250 bbls. in the first two days. It now yields about thirty bbls. by pumping. Others that have come in dry, as the Clymer well, are converted by a "shot" into productive pumping wells. The last named well yields ten or fifteen bbls. a day. But generally the first behavior of the well is an index to its true character.

As may be inferred from statements already made, the geology of the Lima field is substantially one with that of Findlay. The whole region is underlain with the Waterlime, the rock being exposed and quarried in the deeper valleys in and around the town.

The elevation of Lima is about 100 feet greater than that of Findlay. Unfortunately, the elevations given by the several railroad surveys do not agree.

The elevation of the track at the Dayton & Michigan depot, as given by this road, is 859 feet above tide. A probable correction of fifteen feet will bring this figure to 874 feet. By the Lake Erie & Western railroad, the elevation of the same point is given as 885 feet, and by the Pittsburgh, Fort Wayne & Chicago railroad as 873.5 feet. The track of the Chicago & Atlantic road, on the south side of the town at the station, is given as 903 feet; but this measurement is entirely independent of the others. These discordant figures have not been harmonized, but inasmuch as the Lake Erie & Western elevations have been used in the Findlay field, the figures of this road will be used here also, although it is probable that they are about eleven feet in excess.

Almost all of the town, and of the county adjoining it for sev-

eral miles on either side, will be embraced within the range of 850 to 900 feet above tide (L. E. & W. crossing, 885).

The oil wells range from 1,240 to 1,290 feet in depth. The surface of the Trenton, in fourteen of the first twenty wells drilled, the extremes of which are twelve miles apart, ranges as follows:

390	feet	below	tide.
390	"	"	"
393	"	"	"
394	"	"	"
395	"	"	"
395	"	"	"
396	"	"	"
400	"	"	"
403	"	"	"
406	"	"	"
407	"	"	"
421	"	"	"
432	"	"	"
445	"	"	"

The first ten of the list are located in Lima, or immediately adjoining it.

The records that the wells have made, with reference to oil production, are significant in this connection.

The first two wells flowed oil when the rock was struck (Trenton, 390 below tide).

In the third case, the oil flowed after the well was torpedoed. (Trenton limestone, 393).

The four wells next on the list are all pumping wells, and yield an average of about twenty bbls. Several of them have been torpedoed with good results as to production, but without converting them into flowing wells. (Trenton limestone, 395-396).

The remaining wells (Trenton limestone 400 feet and more below tide) are all practically failures. It is claimed that the well in which the Trenton is 406 feet below tide would, if pumped, prove a ten-bbl. well, but neither this nor any of the others is pumped at the present time. The last three are plugged and abandoned.

It is surprising to see on what a narrow margin success in

drilling has thus far turned. It is scarcely possible that this margin will be maintained throughout the field, and the results of later drilling will prove very interesting when brought into comparison with these earliest figures, but thus far certainly geological structure is seen to be connected in a most important way with the yield of oil from Lima wells, and especially with the differentiation of these wells into the several groups already named.

The salt water in any case lies very near the oil. In many wells both are constantly produced. If the pumping is stopped the salt water overcomes the oil. A cessation for a single Sunday in the Citizens' well reduced the daily production of oil from eleven to eight and one-half inches in the tank, and it required steady work for an entire week to restore the flow. In such cases it would seem that a short stoppage would prove fatal. The brine is of the peculiar character already noted in the other fields, being more of a bittern than a brine. It is produced from the wells perfectly clear, and with a temperature of 80° F. In many of the wells it is counted no special disadvantage, but is pumped steadily with the oil. It cannot be separated under ground, whether disadvantageous to the well or not.

Character of the Lima Oil.

The Lima oil is a *limestone* oil, which is as much as to say that it is a dark, or black, sulphuretted, and rather heavy oil. In these respects it agrees with Canada and Tennessee oils. There is quite a range in gravity, however. In the first well, the oil had a gravity of 36° B., but in most of the later wells it reaches 37° or 38°, and in the McCullough well it reaches the high mark of 41° B. Several tests have been made on a fairly large scale, and the results show that the oil can be completely deodorized, that it carries sixty-five per cent. of illuminating oil, and twenty-six per cent. of lubricating oil of excellent quality, and other merchantable products.

These results were obtained in Canada refineries where several barrels were sent, and they are, on the whole, the most favorable that have been reported. The oil was thoroughly deodorized, and each of the several products showed high or fair quality.

From a test made in Philadelphia, a somewhat better percent-

age of illuminating oil was reported than that given above, but the products were unmarketable by reason of their offensive odor.

The Downer company, of Boston, also makes a favorable report.

The latter company has united with the Edwards Oil Burner Company, of Chicago, to establish a refinery in Lima, and here, without doubt, the best results will be speedily obtained. The work of construction is already going forward, and refining operations will be undertaken at an early day, in which the best appliances and the highest skill will be employed. The refinery will have, on completion, a capacity of 250 barrels per day.

The promise of the field depends largely on the success of this undertaking. At present, the price of Lima oil is forty cents per barrel, and there are many wells that can not be pumped for what they yield, but if the value of the oil could be increased fifty or more per cent. their production could still be maintained. The increase of price is to be looked for from the success of refining operations at home.

Tankage and Transportation.

Indispensable to a modern oil field are the great systems of storage and transportation that American practice has evolved. The Lima field is soon to be supplied with large tanks and with pipe lines. In fact, the work in both is already well under way.

The Buckeye Pipe Line Company, which is an organization under the same management as the National Transit Company, has nearly completed one 36,000-bbl. tank, and has two others of the same size already ordered. The usual system of piping the wells will be at once introduced, and thus the transfer of oil will be accomplished with as great dispatch and as little expense as possible.

Extent of the Field.

The Lima oil field proper extends from the central portions of the town eastward and southward. Comparatively little drilling has been done to the westward or northward, or north-eastward, the earliest ventures being such as to discourage further exploration in these directions. A good well has been obtained three miles to the south-east of town, and the interval is now being quite

thoroughly tested. The field may be held to extend as far as a fairly continuous series of wells can be followed. Its eastern boundary is not yet defined, but enough wells are now in progress to furnish important testimony in regard to it when their records are complete. Even the districts in which failures have thus far occurred are not to be considered as beyond hope, but patches of productive territory are likely enough to be found within them, under the thorough search that is now going forward. It would be unprofitable to attempt to lay down the metes and bounds of a field in such an active stage of development as Lima is now passing through.

THE BLOOMDALE GAS WELL.

A very important extension of the Findlay gas field has lately been made by the sinking of a successful well at Bloomdale, a village of Wood county, on the Baltimore & Ohio Railroad, seven miles west of Fostoria, and ten miles north-east of Findlay. This well was drilled in May, 1886. The casing stands at 755 feet above the sea, and the Trenton was reached at a depth of 1,115 feet. Its upper surface is thus seen to be 360 feet below sea level. It is about this level that all the greatest gas wells at Findlay have been found (Karg, 347; Cory, 350; Briggs, 330, etc.).

The Bloomdale well proves to be one of the strong wells of the district. Its outflow was measured on June 16, but the results obtained were somewhat discordant. Enough was learned of it, however, to warrant the statement that it probably stands next to the Cory well of Findlay in production, the Karg well, of course, being excluded from comparison. Its daily yield at present does not vary much from 3,000,000 cubic feet.

The discovery of this vigorous supply at a distance of only seven miles from Fostoria, an ambitious and enterprising town that has thus far vainly sought for gas within its own boundaries, two wells having been drilled to the Trenton limestone, is one of the important facts of the later developments of the field. The new territory will be fully tested forthwith, and Fostoria will at once proceed to pipe the gas as far as it is necessary, test wells being drilled in the interval between the two towns.

Such a supply is of much greater value to a community than one that is found within the town boundaries, and thus easily

accessible to all land-owners. There is better promise of its having a full term of life, and the capital invested in its development may, under such conditions, secure a due reward. Manufacturing enterprises can more safely be established on such a supply.

Bloomdale of course, may repeat to a limited extent, the experience of Findlay, and sink a number of unnecessary wells, but it is to be earnestly hoped that this ruinous policy will be avoided, and that gas will be drilled for here only when it is needed, and when proper provision has been made for its use.

The results of new explorations in this field will be watched with great interest.

THE TRENTON LIMESTONE IN OTHER FIELDS

As already stated, Bowling Green and Lima were the first two towns to follow the example of Findlay in drilling to the Trenton limestone, and both were successful in their search. It was a strange fortune which made the first three efforts so nearly exhaust the successes in this entire field, up to the present time. With this early record in hand, it seemed to all north-western Ohio, that in regard to natural gas and oil, it was but to ask and to receive. For a few hundred dollars the drill could be sent to what was believed to be a universal and perennial supply of light and heat and power.

Of the twenty-seven counties that occupy in a solid block north-western Ohio, extending from Dayton and Springfield northward, and from Sandusky, Bucyrus and Marion, westward, every one has sunk, or is now sinking a well to the new found region, viz: Trenton limestone. In a number of these counties more than one well has been drilled, and in some, a half dozen, but it still remains true that with a single exception, and that a not very important one, the three counties of Hancock, Wood and Allen, contain all the really valuable supplies that have been so far found.

THE CAREY GAS WELLS.

Of the towns that have attained a measure of success outside of those already named, Carey, Wyandot county, deserves mention.

Two wells have been drilled here, the first of which found a small, but thus far persistent flow of gas from the Trenton lime-

stone. The depth at which the Trenton was struck is 1,326 feet. The elevation of the well-head above the sea is about 813 feet, and consequently the upper surface of the Trenton is a little more than 500 feet below tide. This is the lowest point in the rock in which gas in any notable volume has been found. The closed pressure of the well is reported at 335 lbs., but no measurement has as yet been applied to its outflow.

A second well that was drilled here is reported as smaller in production than the first. Other wells are likely to be drilled at this point, but thus far there is no indication of high-pressure gas in this field. The supply, if it is maintained, is, however, well adapted to domestic use and to the production of steam for ordinary purposes.

THE FREMONT GAS WELLS.

Fremont, the prosperous county seat of Sandusky county, has taken a lively interest in the new-found fuel of northern Ohio from the date of its discovery in Findlay. The first well was drilled here in the summer of 1885. The Trenton limestone was found about 700 feet below sea level.

Gas was found in small amount in the shales that were traversed by the drill, and especially in the Medina horizon. The Trenton limestone did not make, in fact, very notable additions to the supply obtained before it was reached. The whole amount of gas flowing from the well a month after it was completed was less than 10,000 cubic feet per day.

A second well that was sunk soon afterwards was more successful, but it was also apparent here that the gas came in large part from the Medina or Hudson river shales. In the wells next drilled, the upper sources only were reached, the wells not being sunk deeper than 600 feet. These shallow wells are the best of the field thus far, but they are small producers. The second in force gives by meter, 17,000 cubic feet per day.

The gas is excellently adapted to domestic use, but the wells lack the force and vigor necessary for a manufacturing supply.

Eight wells have been drilled up to the present time, and more are under contract.

There are nearly or quite fifty other towns of the western half of Ohio that have been inspired by the success of Findlay and

Lima, to drill to the Trenton limestone within the last eighteen months. Most of these towns have already completed one well, and several of them have undertaken a second or even a third. In a number of instances, the drill has been carried down hundreds of feet into the Trenton limestone, but without advantage in any case. Nothing has been gained from below the uppermost fifty feet of the limestone.

Some of these wells are absolutely "dry," and are acknowledged to be unsuccessful ventures. Even to nitro-glycerine they make no favorable response. In a much larger number, oil and gas have been found in small quantities. Of the latter class, some wells will yield a few hundred or a few thousand feet of gas per day, or from them a few barrels of oil have been or can be obtained. Wells of this character are often counted by the companies that have drilled them as very different from "dry holes." They are thought to give fair promise to the fields in which they occur and to justify further exploration. The first well in Lima made but a poor production of oil, and much account is made of this fact. There are many towns in Ohio that count their first wells as promising as the first Lima well, and they draw from this comparison much encouragement, much more, indeed, than the facts when fairly understood will justify.

The history of a score or more of these wells is substantially as follows:

When the drill has been sunk ten to forty feet into the Trenton limestone, oil is found, generally, in small quantity, but sometimes it rises in the well for several hundred feet. Of course, a little gas accompanies it. To secure a large flow, the drill is kept at work and presently salt water is struck. Sometimes, in fact, the oil and salt water are reached at exactly the same point. The salt water also rises in the well, carrying the oil above it, and occasionally causing overflows. The entire column is generally credited to the oil account. The baler is set to work, and a half dozen barrels, more or less, of oil are obtained. At this point, the well is either tubed and packed, or it is "shot" and made ready for pumping. Generally the latter course is taken, and thirty or forty quarts of nitro-glycerine are exploded in it, at the level of the oil producing rock, after which the tubing is introduced. A tank is frequently constructed and the pump is set to

work. For a few hours the promise is fairly good, and five, ten, or even twenty or thirty barrels of oil are delivered. At this point, salt water begins to appear, or production of all sorts may be arrested. The decline is generally attributed to sand in the valves. The pump is drawn but nothing is found wrong. After an interval, a little more water and less oil are pumped, or perhaps a steady flow of brine appears, but presently it is found that no more petroleum is available in this particular well. But it is often held that the well has been successful in demonstrating the presence of oil and gas in the field, and that now it only remains to find the particular localities where they occur in "paying quantities." The first well, it is believed, was carried a foot or two too deep, but when a second well is drilled, no amount of care prevents a repetition of the experience of the first.

It would be a pleasure to record the success of any field whose history opens in this way, but thus far no opportunity has been given. Oil and gas in "paying quantities" still remain to be discovered in such districts.

Wells of this character are much worse for the towns that find them than dry holes, because encouragement is often derived from such facts for a second and a third venture, which have thus far, in every case, resulted in the same way as the first. The first Lima well is not a case in point. It was not handled properly for an oil well, being the first in the field. Practical men saw from the record that its promise was fair.

The further tests that have been undertaken will doubtless supply, during the present year, materials for a more decisive judgment in the case of many of these districts, and nothing need be said to cloud their titles at the present time, except as they may be involved in certain general conclusions that are now to be stated.

CONCLUSIONS AS TO THE NEW FIELDS.

1. From the facts already stated, it is obvious that the discovery of oil and gas in the Trenton limestone of northern Ohio is invested with great economic interest and importance in the localities that have been specially named. Fuel of such character as Findlay gas, has become in our day a factor of the greatest value in many lines of manufacture, and the towns that can secure

it gain such an advantage that competition with them is difficult or impossible on the part of towns that are without it.

Oil is, in like manner, power. In addition to all other uses, it furnishes the best of fuel. Excellent facilities for using it as fuel have been provided of late, and some of these are already introduced on the large scale into Lima and adjacent towns.

The eager search for the new fuel, whether gas or oil, that has been going on and that is still continued in the State, is fully explained, and in a measure justified by the extraordinary value of these substances when found at their best.

2. The supply of valuable accumulations of oil and gas from the new horizon has thus far been found to be very sharply limited. There are four productive centers at the present time. Others will doubtless be added, but probably within or near to the general boundaries already pointed out. The inference that was hastily drawn from the experience of the towns that led in the search, viz: that all of northern Ohio is good oil and gas territory, has been proved to be unfounded. The oil of Pennsylvania and New York has all been derived thus far from less than 400 square miles of working territory, but these 400 square miles are distributed through many thousands, and even through tens of thousands of square miles. The production of the Trenton limestone in Ohio may prove to be as sparsely and as apparently capriciously distributed throughout the districts which it is known to underlie as is the production of the great sandstone sheets of Pennsylvania.

3. The productive territory lies in *spots*, and the different centers cannot be connected by any lines or belts that it is at all worth while to draw. Any two places can be joined on the map by a straight line, it is true, but not a line can be drawn between the productive districts at present known, which is not broken by failures where drilling has been attempted, and no line has yet been found that would lead the driller to fortune. The north-east and south-west line derived from Pennsylvania experience, is perhaps, the favorite direction in the new field also. Lima lies to the south-west of Findlay; so far, good, but in the same line lies Fostoria with two dry holes, Fremont, without a single well in the Trenton that deserves mention, out of a total of eight wells. Between Lima and Findlay, wells have been drilled at four points, viz: Beaver Dam, Bluffton, Mt. Cory and Rawson, and all are

failures. To the south-west of Lima is Celina, where the Trenton is reported unproductive. Out of a total of nine locations on this line, two are productive.

Another line on which great expectations have been built, is the north and south line connecting Findlay and Bowling Green, but the line is broken in the middle and at both ends. Between Bowling Green and Findlay, the North Baltimore well has showed unproductive ground, at least in the first well. North of Bowling Green are the three unproductive wells of Toledo. South of Findlay, Arlington, Kenton, Belle Center, Urbana and Springfield have made an unavailing search for oil or gas in the Trenton. In this case, two localities out of nine in the line have proved successful. Such lines or belts, it is obvious, are worse than none.

The Canada oil field is frequently included in the same belt with Lima and Findlay, but the Canada oil is derived from a rock that is not present at either of these last named points. Its place in the Findlay scale would be 300 to 400 feet in the air. The Corniferous limestone is the Canada oil-rock, and the Trenton is never approached within a thousand feet in this field, and moreover, there is good reason to believe that the Trenton arch in Ohio was formed ages before the Canada oil rock was deposited.

4. The most important line of facts that has been brought out thus far by the study of the field is the connection which is found to be maintained between the productive areas of the Trenton limestone, and the level which its surface holds with reference to the sea. All of the present production is derived from a quite narrow range of elevations. The gas wells of Findlay find their supply where the limestone lies between 306 and 350 feet below sea level. The *great* gas wells of the field are thus far included in the interval between 330 and 360 feet, both included, below sea level. The gas wells of Bowling Green, including Portage, all find the Trenton at 380 to 400 feet below the sea.

The oil of the several fields has scarcely a wider range. The deepest steady supply of oil comes from the Matthias well, at the foot of the Findlay slope, where the Trenton limestone lies four hundred and eighty-one feet below the sea. The bulk of Findlay oil, however, comes from between four hundred and four hundred and sixty feet below the sea. Lima oil is derived from the Trenton, where its surface ranges between three hundred and

ninety and four hundred feet below the sea. It is highly probable that wider limits will be established under the active development that is going forward, but up to the date when the facts were taken, all the wells agreed fully with the statements here given.

In the Lima district, the descent of the surface of the Trenton to four hundred feet or more below sea level, is instantly fatal to it as a source of petroleum.

In no case has oil thus far been produced in any persistent supply from the Trenton limestone where its surface is five hundred feet below the sea. The deduction is obvious. Where the surface of the limestone is found five hundred feet or more below the sea, one well is enough to determine the character of the immediate field, according to present knowledge. The Carey wells mark the limit in this direction. The Trenton limestone here lies five hundred and thirteen feet below sea level.

The provisional character of this conclusion is fully recognized. It will lose its validity when set aside by a new fact, but so long as it is maintained it can be made useful in limiting exploration as already suggested. Large districts are promptly condemned by this deduction. It may be charged that this is a prophesy after the fact, that only by the failure of the well can the law be extended. It is true that a certain amount of exploration must precede a valid conclusion, but the latter is by no means limited to the particular districts in which the exploration is carried on. Take for example, the drilling that has gone forward in towns on the Dayton & Michigan railroad, north of Lima. In the well drilled at Columbus Grove, the Trenton was struck at five hundred and twenty-six feet below sea level; in the Ottawa wells, at six hundred and thirty-nine feet; in the Leipsic well, at seven hundred and one feet, and in the Weston well, at nine hundred and five feet. At Toledo, also, its surface was found eight hundred feet or more below the sea. Not only is further drilling in these localities discouraged by this conclusion so long as it stands unimpeached, but the geological structure of the counties to the west of this line is such as to make it certain that their condition is worse in this respect than that of the towns that have already experienced failures. That is, the Trenton limestone lies lower in them than in the regions already found barren. In Van Wert county, however, west of Lima, the Trenton is found at a level

more favorable, so far as this deduction is concerned. Its surface in the Van Wert well is four hundred and thirty-four feet below the sea, and in the Delphos well, four hundred and forty-seven feet below. Further exploration may well enough be undertaken in this region.

By the application of the same deduction, the eastern boundary of the field lies along the line of the Columbus, Hocking Valley & Toledo railroad. Wells have been drilled on this line at Marion, Upper Sandusky, Carey, Fostoria, Bradner and Toledo. The record of the Marion well is not satisfactory. According to the current figures, the Trenton limestone here lies at about seven hundred feet below the sea; at Upper Sandusky, it is four hundred and seventy feet below; at Carey, where it produces a moderate amount of gas, it lies five hundred and thirteen feet below; at Fostoria, where two dry holes have been drilled, it is four hundred and seventy-two feet below; at Bradner, five hundred and twenty-nine feet below, and at Toledo, as previously stated, about eight hundred feet below sea level.

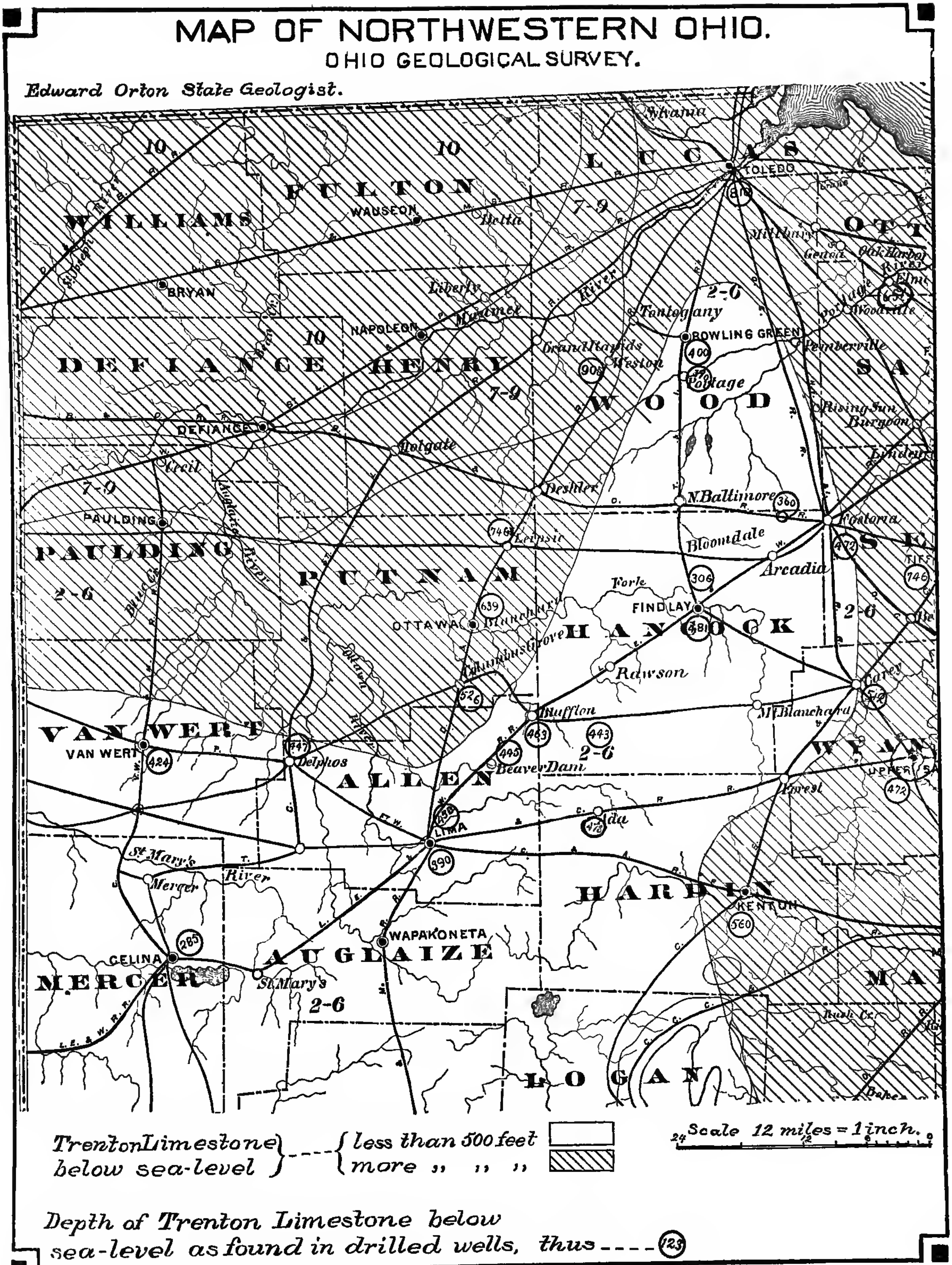
The line of elevations here given belongs, of course, to the counties already named. There is no known significance as yet, outside of these districts, in the fact that the Trenton limestone lies three hundred or four hundred feet below the level of the sea, so far as oil or gas production is concerned. The limestone, as already shown, rises slowly to the southward. Its upper surface reaches sea level not far from the parallel of Dayton. At Cincinnati, it is about two hundred feet *above* sea level, though still buried several hundred feet deep, and in the valley of the Kentucky river, it rises to-day, having here an elevation of five hundred to six hundred feet above the sea. Through the northern portion of Darke county, through Shelby county and probably through Logan, there is an arrest of the northward dip and a small reverse dip is established. The Trenton lies forty feet higher at Union City, Ind., than at Greenville, and forty feet higher at Sidney than at Piqua. This interruption might well be expected to connect itself with oil or gas accumulation, but so far the limestone in this belt has proved entirely barren.

The deduction as to the connection between its petroliferous character and its absolute level is not, therefore, to be applied much beyond the south line of Allen county, according to present

experience. It seems almost certain, however, from the latest developments, that portions of Auglaize and Hardin counties will yet be found to hold valuable stocks of oil or gas. They are very closely connected with producing territory. But the result of a considerable amount of drilling done to the south of this line is certainly discouraging. At no point has the limestone been found charged with oil or gas in sufficient quantity to pay for the present or to warrant further exploration. More than twenty-five wells, distributed through thirteen counties, have been sunk to the Trenton limestone within this district, but the rock has not yielded to a single one of them any adequate return in the way of light or heat. At Cincinnati, these wells do indeed furnish power, but it is water power. They have proved artesian wells, and the strong flow which they send out from the deeper courses of the Trenton is utilized in elevators. New wells are being drilled for the express purpose of securing this form of power. The deep water of these wells is quite highly mineralized, and is popularly identified with the Blue Lick water of Kentucky. Some value is attached to it as a medicinal water at several points where it has been reached.

In the accompanying map of a number of counties of north-western Ohio, the areas in which the Trenton limestone is found more than 500 feet below sea level, are indicated by shading. The north-western and the north-eastern boundaries are established on a larger number of facts than the remainder. In Hardin county, particularly, and also in Logan, the lines laid down have but little to rest on, and not much reliance is to be placed in them. Much of the boundary is provisional only, and when more facts are in hand the included areas will possibly be represented by an archipelago instead of by a single mass. One outlier of Trenton less than 500 feet below sea level is to be noted at Upper Sandusky. The surface of the rock here is reported at 472 feet below the sea.

No large production of oil or gas has been obtained in any of the shaded areas thus far, but it is not to be inferred that all of the unshaded portion is promising territory. Much of this has been already found barren by the drill. It is also to be considered fairly probable that accidents of structure like those described in Findlay may somewhere determine production in the regions that thus far we have been obliged to condemn.


MAP OF NORTHWESTERN OHIO.
OHIO GEOLOGICAL SURVEY.
Edward Orton State Geologist.
WILLIAMS
FULTON
LUCAS
DEFIANCE
HENRY
WOOD
PAULDING
PUTNAM
HANCOCK
VAN WERT
ALLEN
HARDIN
MERCER
AUGLAIZE
LOGAN
TOLEDO
WAUSEON
BRYAN
NAPOLEON
DEFIANCE
BOWLING GREEN
PAULDING
OTTAWA
FINDLAY
VAN WERT
LIMA
WAPAKONETA
CELINA
KENTON
Sylvania
Delta
Liberty
Tontogany
Grand Rapids
Weston
Portage
Pemberville
Rising Sun
Burgoon
Holgate
Cecil
Deshler
N. Baltimore
Fostoria
Leipsic
Bloomdale
Arcadia
Forle
Columbus Grove
Rawson
Bluffton
Mt. Blanchard
Carey
Delphos
Beaver Dam
Ada
Forest
Mercer
St. Mary's
Millbury
Genoa
Oak Harbor
Elmore
Woodville
Maumee River
St. Mary's River
10
7-9
2-6
Trenton Limestone below sea-level ---- less than 500 feet
more ,, ,, ,,
Scale 12 miles = 1 inch.
Depth of Trenton Limestone below sea-level as found in drilled wells, thus ---- 123

Missing Page

It is believed that this conclusion can be applied with great profit to the regions in which drilling is going forward. The towns may still insist on making their tests, but one will perhaps suffice when the record shows the lower limestone to be at a level from which no value has yet been obtained. In fact, all new drilling for Trenton limestone oil or gas, in the shaded areas, might well enough be left in abeyance, until at least one success is registered in such territory. There are a score of wells now under contract in these clouded districts, and if their records all agree with the records already made, it will be as nearly certain as most things are that we call certain, that no new well will repay its projectors. A line showing the 400 feet levels of the Trenton would come much closer to actual production than that here represented, but for the present we must be content with rough approximations to boundaries.

5. The drilling that is now going forward, and that is likely to be continued in the western half of Ohio for some time to come, seems likely to bring little or no reward in money value to the communities that undertake it, outside of the three or four counties previously named. It makes a redistribution of a good deal of accumulated wealth, but the labor is essentially unproductive in character — that is, it does not seem likely to add to the material resources of the parties that make the outlay. There is, however, another side to the question which deserves consideration. The drilling of a deep well in the drift-covered plains of northern Ohio is an educating agency of no mean order. The record, as the work progresses, becomes to a whole community almost like the experience of a journey into a foreign land. A new field of thought is opened, and new ideas come in at every stage. The oil and gas excitement of the last two years has done a great deal to promote the intelligence of the communities through which it has extended. To an ambitious company that has made liberal investments in the hope of gaining a prize in the lottery of petroleum production, the result here named may seem a very intangible and unsatisfactory one, but for a great many of the towns that have drilled, it is either this or nothing. The money spent in drilling to the Trenton limestone in western Ohio during the last year makes a large aggregate, and most of it must be counted as water poured out on the ground, except for these indirect advan-

tages which have no place in ordinary balance sheets. If such elements are not recognized, then Ohio has been a great loser by the discovery of Findlay gas and Lima oil.

It is the lottery element in petroleum production that gives to it most of its fascination. As in the search for other forms of mineral wealth, there is the possibility of getting large returns for small outlays. Science has no key with which to unlock these buried treasures in advance of exploration. No knowledge and no sagacity could have located the oil field of Lima, for example, in advance of the driller, but after a certain amount of exploration is done, deductions are often possible by which further work may be guided to some extent. This now appears to be the case in regard to the new oil horizon of Ohio. The element of chance still remains a factor, but the drilling already done suffices to show that outside of certain narrow boundaries the dice are at least loaded. Each new failure gives new validity to the interdict against drilling that the results of one year's explorations have applied to large sections of western Ohio.

The facts here presented when candidly considered will discourage much of the promiscuous drilling that is now going forward. Especially will they discourage the drilling of second and third wells in many localities where the first well was, to all intents, a failure. The excitement that has pervaded the State is largely due to the sensational and exaggerated reports that have been sent out from the points where drilling has been done, by persons gathering news for the press. To one deriving his information from newspaper paragraphs alone, the inference would be warranted that north-western Ohio is one great pool of petroleum, charged with high-pressure gas, and ready to flow out in streams of fabulous value wherever the drill is sunk to the rock that contains it. Much of the production, especially of gas, has been exaggerated a score of times, and some of it even hundreds of times. In one instance, a well was credited in published accounts with 385,000 feet of gas per day, where the measurement showed 1,270 feet. The exaggeration is not, as a rule, intentional, but it results largely from the unfamiliar character of the facts. It will doubtless diminish as knowledge of the subject becomes more general.

The remaining horizons of oil and gas will be very briefly treated in this review. There is but one of commanding importance.

SECTION V.—THE BEREA GRIT AS A SOURCE OF OIL AND GAS IN OHIO.

The stratum here named holds as central a place in the oil and gas supply of eastern Ohio as the Trenton limestone does in northwestern Ohio.

As already described, it is a sandstone formation of medium grain, ranging from five to 100 feet in thickness, and is remarkably persistent. Its identification under cover is rendered easy by the character of the strata associated with it. It always has a black shale roof and often a red shale floor. Moreover, it is the last regular sandstone to be passed in the rocks of the State in descending order. Its outcrop from Cleveland west and south passes through Cuyahoga, Lorain, Erie, Huron, Richland, Crawford, Morrow, Delaware, Franklin, Pickaway, Ross, Pike, Highland, Adams, and Scioto counties. In Pike, Highland, and Adams counties, it attains its highest elevation above the sea, which slightly exceeds 1,300 feet. In Richland and Crawford its outcrops have an elevation of 1,125 feet above the sea, and on the shore of Lake Erie an elevation of about 800 feet.

It dips prevailingly to the south and east at a rate of fifteen to thirty-five feet to the mile. Its lowest levels are found under deep cover in the Ohio valley from Marietta to Steubenville. The lowest recorded levels are about 800 feet below tide. Its vertical range is thus seen to be not less than 2,100 feet.

It is geologically due in fifty counties of Ohio, and it is entirely safe to say that it is present in every one, inasmuch as its presence has been proved in all of those in regard to which a question might most easily be raised. In a number of the counties where it lies deepest, it has been found in scores and even in hundreds of drill holes. Wherever exposed to view it is almost, if not altogether, destitute of organic remains, and its stock of oil and gas is undoubtedly derived from the great mass of bituminous

shale by which it is everywhere underlain. It is like all other oil rocks, a repository of salt water as well. The brine derived from it has been the sole reliance of some of the best salt works in the State in years past, and it is still used at one important center of salt production in the State.

At certain points the Berea grit has proved to be a source of oil and gas when under the lightest possible cover. The well-known oil-fields of Mecca and Grafton furnish instances of this sort. In the first of these fields more than 2,000 wells have been drilled, none of them having a depth of more than fifty or sixty feet. In many of the wells there is no cover whatever for the Berea grit but bowlder clay, the lower portions of which are saturated with oil.

It thus appears that the natural shale cover of the sandstone was all eroded in distant ages. Before this took place, the stratum must have been charged with oil. While lying exposed as a surface rock, oil must have constantly oozed from it, as we find oil and gas escaping from certain outcrops now. But when the nearly impervious beds of bowlder clay had once more formed a cover, accumulation of oil was resumed in the rock, and thus the somewhat scanty stocks that have been drawn upon for the last twenty-five years have originated.

The oil of the Mecca field has lost most of its volatile products through the light cover by which it has been protected, and it now has the usual gravity of 26° to 28° B. It is a lubricating oil of excellent quality, its price ranging higher than that of any other natural oil in market. The present product is limited to a few hundred barrels in a year. The Berea grit at Mecca is about 850 feet above sea level.

In the town of Grafton, Lorain county, a production of similar character was maintained for a number of years. The Berea grit here retains fifty to seventy-five feet of its normal shale cover, but the oil is still a very heavy oil, similar in quality to the Mecca oil. Several hundred wells have been drilled during the history of the field, but none are productive at the present time. The Berea grit at Grafton is about 650 feet above sea level.

As the Berea grit takes heavier cover, it becomes a source of larger production. It has yielded a good deal of gas at several points when found from 400 to 600 feet below the surface. Oil is

also produced by it abundantly under the same conditions. The absolute level at which it is found seems thus far a matter of indifference so far as the production of gas and oil is concerned. It has been found to produce one or both in important quantity when it lies 800 above and 750 feet below sea level.

Two or three fields of special interest will be very briefly treated.

THE EAST LIVERPOOL GAS WELLS.

The gas wells of this region, viz: the Upper Ohio Valley, are more widely known than the importance of their supply would lead us to expect. The utilization of natural gas for household heat and light was effected here in 1874, and has been maintained ever since on a somewhat restricted scale. The village streets have been lighted with natural gas also for the same period.

The gas is obtained from shallow wells, ranging from 425 to 475 feet in depth. The absolute level of the oil-producing rock is about 250 feet above sea level.

The structural features of the field are well marked. A low fold, apparently the Fredericktown anticlinal of White, traverses the strata of the region, lifting the conglomerate coal-measures so as to almost expose their lowest beds. From this point southward the dip of the strata is unusually rapid. Between East Liverpool and Steubenville, a distance of twenty-five miles, there is a fall of nearly 850 feet.

Gas was discovered here, in connection with salt water, in the wide-spread search for oil that extended through the country in 1859 and 1860. A small amount of oil was found here, and at Smith's Ferry, a few miles above East Liverpool, an important field, which maintains a small production to the present time was then developed. The salt water was turned to account for salt manufacture, and, after the Kanawha Valley fashion, the accompanying gas was used in the evaporation to some extent, but it was not until 1874 that the gas began to be used for other purposes, as heating, cooking, etc. East Liverpool is a pioneer town in these later applications of natural gas. It was first applied to the burning of pottery here.

The section passed through in reaching the Berea grit is characteristic. The Cuyahoga shale is a homogeneous mass of light-

colored shale, 200–250 feet in thickness, always underlaid by the Berea shale, dark or black in color, and twenty to forty feet thick. The last named stratum makes the cover of the Berea grit, which seldom exceeds twenty feet in thickness, and which is often reduced to less than ten feet.

The supply is very moderate at the present time. The largest well yields about 35,000 cubic feet per day, and others fall as low as 10,000 cubic feet. Even this production can be maintained only by scrupulous care and attention. All the wells that are used are pumped for salt water once and often twice a day. A few gallons of brine are removed with each pumping, but were it not for this constant removal, the brine would soon overpower the gas and the supply would become extinct.

The gas company keeps five wells in operation. They supply fifty or sixty families, and they also light the streets of the town. The lights are not extinguished through the day. The present supply runs short in severe weather.

The potteries have made repeated and earnest efforts to secure large and vigorous supplies, but the rock has thus far proved obdurate. It will only yield household fuel.

The gas has but little odor, and accidents of the usual character have resulted from its leakage.

The field has been greatly injured by the over-crowding of wells, five or six being located on a half-acre, and also by neglect or abandonment of wells already drilled. There is a good degree of permeability of the oil-rock, as is shown by various facts, and one neglected well pours its accumulating brine into those nearest to it.

THE NEFF GAS WELLS.

A series of wells drilled for oil twenty years ago in the valleys of the Kokosing and Mohican rivers, in the north-western corner of Coshocton county and in adjacent territory, has become widely known through the large production of gas from two of the wells and the continuous production from several others, and through the utilization of the gas in the manufacture of lamp-black in the large way, an important and quite widely-extended application which, so far as is known, originated here. The manufacture is still maintained at this point in considerable force.

The whole enterprise in the way of development and use has been under the management and control of Peter Neff, Esq., of Gambier.

Quite a full account of the wells and of the early stages of the lamp-black manufacture is given by M. C. Read, Esq., in Geology of Ohio, Vol. III, page 340, etc.

Mr. Read referred the oil-rock to the horizon of the Berea grit, and established the probable presence of arches or similar structural derangements in the series at this point and in the neighborhood, the normal dip of the oil-rock being found to be reversed in some of the wells.

The Berea grit lies from 550 to 600 feet below the surface of the valleys, and between 250 and 300 feet above tide-water. Oil has been produced from some of the wells in small quantity; all of them yield more or less salt water. Two of the number proved to be very energetic gas wells of the geyser type, but the gas has been gradually reduced by the salt water. The three wells that are now the dependence of the lamp-black manufacture are comparatively small producers, and need constant attention in the way of removing the brine that accumulates in them. They are pumped each day for this purpose.

The field certainly shows some promise as a gas field. Further developments conducted in the light of our recently acquired knowledge of gas and oil accumulation, might fairly be expected to find some points at which the gas would not be so closely followed and hard pressed by salt water. The chief drawback is the distance of the location from any center of established industries that could make use of a large production.

The wells were drilled for oil, as has been said, and great disappointment was experienced when only noisy and ungovernable gas wells were found. The discovery of such stocks of gas to-day would create a greater interest than any ordinary oil wells in most parts of the State. The disappointment now is when gas is missed and oil is found in most of the explorations in progress.

THE MACKSBURG OIL FIELD.

This is the only important oil-field of the eastern half of Ohio at the present time. There are four productive sand rocks in this field, but the interest centers in the Berea grit. This stratum was

first struck here in 1877, the first well yielding only dry gas. In 1878, the first oil well was obtained in the Berea, a ten-barrel flowing well being struck by George Rice, Esq. In 1882, a well flowing 100 barrels per day was obtained, and the attention of Pennsylvania oil-producers was forthwith definitely turned to Macksburg. It speedily became a factor in the general market, and has produced since that time as much as 3,000 barrels per day for a maximum. Its yield for 1885, was over 600,000 barrels. Its present output is about 2,400 barrels per day. Over 400 wells are now producing, and the average yield is about 6¼ bbls.

The Berea grit is found here in a normal and unequivocal section at 1,450 to 1,500 feet below the valley levels. The peculiar structure brought to light by a careful study of the field has been adverted to on a preceding page. It was first noted and worked out in a preliminary way, by F. W. Minshall, Esq., of Parkersburg. Lines of level were afterward run over all the field by the Geological Survey, and Mr. Minshall's reading of the stratum was confirmed at every point.

The leading facts are as follows: In the vicinity of Macksburg, the light, south-easterly dip of the strata is found to be interrupted, and for nearly a mile in the general direction of the dip, a terrace-like structure prevails. All of the strata of the exposed section from top to bottom, and all that are ever reached by the drill as well, are equally affected by this structural irregularity.

It is this terrace which constitutes the Macksburg oil field. Oil was found here 20 years ago in shallow wells from 200 to 300 feet deep in the Buffalo (Upper Mahoning) sandstone. But adventurous drillers, one after the other, struck new sources of oil. A second oil sand was soon discovered at 500 feet, and a third at 700 feet. Finally, as before stated, the Berea grit was found 1,300 to 1,500 feet below the surface, holding a stock of oil large enough to make the Macksburg field for the first time a factor in the general market.

But the shallow and the deep productive wells are alike definitely limited to the terrace that has been described. In other words, four oil-sands become productive in the same area when the structure is found favorable. That these several horizons do not communicate with each other is evident from the fact that the

oils which they severally produce differ from each other in gravity, in color and in chemical constitution.

The depth of the Berea grit in the terrace below sea level is 735 feet. Of twenty-four wells, distributed through four square miles of territory, sixteen found the Berea between 733 and 737 feet below tide, and six found it, by their records, to be exactly 735 feet below tide.

On the north-western margin of the terrace, at elevations of 728, 720, 713 and 704 feet, gas is found but no oil. Several hundred wells have now been drilled on all sides, and the terrace which stands revealed by the engineer's level is alone found productive.

THE WELLSBURG GAS FIELD.

A gas field developed in the Ohio valley, between Steubenville and Wheeling, demands brief mention here. It embraces territory on both sides of the river, but the center of the production is at and near Wellsburg, W. Va., and the field is best known from this locality. The search for gas in and around the chief manufacturing centers of this part of the valley, as Steubenville, Martin's Ferry, Wheeling and Bellaire, has been very resolute and persistent. More than 50 wells have been drilled here within the last three years, the average cost being at least $3,000. The manufacturing industries of this region are mainly in the lines of iron, glass and clay, and it is precisely these industries that are most affected by the introduction of the new fuel. The manufacturers of this district have recognized the absolute necessity of securing natural gas from some source to maintain themselves in the field, but thus far they have succeeded only in demonstrating that they have no home supply except in a comparatively limited range, and that unfortunately at a considerable distance from the points where the demand is most urgent.

In December, 1882, a gas well of great vigor and promise was drilled at Wellsburg. It is known as the Barclay well No. 1. Gas was found all the way down in the descent of the drill, but at 1,277 feet a great flow was struck. This flow came from the Berea grit, which was found here ten feet thick, and under 400 feet of Cuyahoga and Berea shale, above which were 250 feet of the pebbly series of the Waverly and coal measure conglomerates.

Under the Berea at Steubenville, the drill descended through 800 feet of Ohio shale without profit. This pioneer well served to accredit the field, but it has rendered comparatively little service in other ways. It blew its great volume of gas into the air for nearly a year, and through various causes lost much of its initial energy. It was then "drowned" by the flood of 1884, and since then has never recovered its pressure. A measurement made of its flow by the anemometer in July, 1885, showed its daily yield to be 30,620 feet.

A second well drilled very near it in April, 1883, known as the Barclay well, No. 2, has proved a fairly vigorous producer. Its yield in July, 1885, was found to be 469,000 feet per day.

This immediate location has been ruined, however, by the crowding of wells together, and by the neglect of some of the number. The territory is overrun with salt water, and no longer is counted valuable.

Other wells, the noted Dalzell well among the number, were soon added to the list, and for several miles on both sides of the river, drilling went forward on a large scale. The Ohio side was vigorously worked, and wells of some promise were struck at Brilliant, but their life has proved short.

In fact, the entire supply of the district is reported as running low, and the field fails to fulfill its early promise.

Of the eight wells drilled at Steubenville, all have proved virtually failures.

So far as present knowledge goes, there is but one source of petroleum in valuable quantity and of high-pressure gas available to north-eastern Ohio, and that source is the Berea grit. The statement cannot be made quite as strong for the south-eastern quarter of the State, inasmuch as the Waverly conglomerate, and several strata of the conglomerate coal measures, and also the upper division of the coal measures furnish, at times, both oil and gas in valuable amount, but when all is said, the Berea grit outranks in importance in these respects all the rest combined. The stratum that yields the Macksburg oil and the Wellsburg gas is the only one on which either the oil producer or the manufacturer who is seeking for natural gas can afford to make much outlay in that portion of the State.

In all the localities of north-eastern Ohio in which the Berea

grit is found barren or but feebly productive, home supplies of high-pressure gas are not to be expected, and while in south-eastern Ohio there are one or two chances besides those furnished by the Berea grit, and which indeed, must be taken before the Berea grit is reached, they are too uncertain to inspire confidence or to warrant large expenditure. In point of fact, there is at the present time no production of either oil or gas in the eastern half of Ohio that is not derived from or that does not draw its value from the stratum under consideration. The last clause refers to the production of the upper oil-sands of the Macksburg field. By themselves, these last named supplies would be insignificant, but in conjunction with the oil from the Berea grit, they acquire new value and importance, being able to avail themselves of all the advantages which the latter has secured.

The recognition of these facts would have saved, within the last year, to the towns of north-eastern Ohio, a large amount of money that has been used to no purpose in drilling unusually deep wells in search of natural gas. Their recognition at the present time will discourage for years to come, like large expenditures in random drilling in the same search. Test wells, involving possible new horizons, when located wisely and when followed with due care and with all available knowledge, will always be in order, but the work that is now going on mainly consists in driving deep holes into the ground, the work being guided by scarcely more intelligence than would be used in turning a wheel of fortune. Chance will always have a considerable part to play in the distribution of mineral wealth of this character, but there is certainly room for other factors in the search for gas and oil in Ohio at the present day. We are able to avail ourselves of a vast amount of expensive investigation by which our own work should be guided, and in many cases restricted for time to come.

As has already been shown, high-pressure gas and oil in "paying quantities" have not thus far been found in the Trenton limestone where its surface falls 500 feet below the level of the sea. This dead-line of the Trenton passes not far from, but generally a little west of the Columbus, Hocking Valley & Toledo railway, through the counties of Wyandot, Sandusky and Wood. From this boundary eastward, until the Berea grit is found under respectable cover, say 300 to 500 feet, there is an interval of 40 to 140

miles in which so far as present knowledge goes, the conditions for high-pressure gas do not occur. The line of the Cleveland, Columbus, Cincinnati & Indianapolis railway, through the counties of Richland, Huron, Lorain and Cuyahoga to Berea, and thence a line running through the central part of Cuyahoga, Geauga, and Trumbull counties to Pennsylvania, will make the eastern and northern boundary of an interval in which the Trenton limestone lies too deep to be available as a source of high-pressure gas, and in which the Berea grit cannot serve such a purpose, either from the fact that its outcrop does not extend so far, or from the fact that it lies too shallow to have acquired large accumulations. To the eastward and southward of this new boundary throughout the eastern half of the State, this persistent stratum is to be counted on as present and ready to take its part as a reservoir of oil in quantity or of high-pressure gas whenever and wherever the other conditions for such accumulation are found. The Trenton limestone is, of course, at still greater disadvantage in this area. Its horizon has dropped so low that no driller has been adventurous enough to find it, and in fact, there is no certainty that we should know it if we reached it. At the center of this old gulf, it is quite possible, perhaps even probable, that the limestone growths so characteristic of this great stratum along a thousand miles of soundings would be replaced by very different materials. Limestone might well give place to shale or other fine-grained deposits.

The boundary within which the Berea grit may be counted ready to perform its part in furnishing high-pressure gas has been roughly traced from the Pennsylvania line into Richland county. Southward from Shelby, the same boundary would extend along the east line of Morrow county, the western central portions of Licking and Fairfield, the western boundary of Hocking, the eastern boundary of Ross, and the central parts of Pike and Scioto. Through all the portions of the State that lie south and east of this boundary, the Berea grit is under 300 feet or more of cover which consists first of 30 to 50 feet of the black or dark close-grained Berea shale, over which, when the full section is reached, 300 to 500 feet of Cuyahoga shale is found, light-colored, compact, and fine in grain, and almost thoroughly impervious. It is underlain throughout its whole extent, on the other hand, by never less than 300 feet of bituminous shales, which are sometimes condensed into

a fairly homogeneous mass, as on the western border, and sometimes interstratified with, and distributed among, five or six times as much lighter-colored, green, gray, or blue shales, as in the interior of the basin. As for the Berea grit itself, it is always a porous rock, though seldom a coarse one. Some of its best work as reservoir for oil and gas is done by it where its grain is below, rather than above the medium grade.

Here then are source, reservoir and cover in perfect order, and on the largest scale, adjusted to large, to even the largest production of oil and gas.

How often do they reach such production? The meager list of localities already given, embraces the important fields that are now known. We have reason to expect that this list will be somewhat, and it is to be hoped, considerably expanded under the explorations that are now going forward.

But it is safe to prophesy that the new fields, like the old ones, will ally themselves in all instances with irregular and abnormal structure of some sort, with broken stratification, with low arches, or in default of folds with the terrace-like areas already described, which in reality are folds that nature began to build but was not able to finish. Throughout how many portions of the main district under consideration, these fortunate misfortunes, these happy accidents of structure are wanting, the drill is constantly making known to us by the negative results of its work.

Within this main area of Berea grit territory, there is no known source of high-pressure gas below the Berea itself. We might well expect some such sources, especially in the northeastern corner of the State, because the Venango, the Warren and the Bradford sands of western Pennsylvania, the most remarkable repositories of petroleum and gas yet found in the world, belong in the interval between the Berea grit and the Corniferous limestone, but they appear to have almost or altogether fined out and disappeared in passing to the westward. Obscure hints of sandstone in the underlying shales of the Ohio section are all that we generally meet, and in no case has important accumulation been found in these possible representatives of the great Pennsylvania store-houses.

The Corniferous limestone itself, as has been already pointed out, apparently holds all of the conditions of successful accumula-

tion of petroleum. It has ample stores of oil within itself, it has also ample thickness, and its cover would seem to meet all demands in that respect, but no valuable accumulation has thus far been found within it within the limits of the State.

The Berea grit has shown considerable vigor in past years in the counties of Hocking and Vinton. There are developments going forward now on this stratum in these counties, and also in Perry and Muskingum that will be watched with interest, but there is not yet any well marked productive territory made known.

Before drawing certain practical conclusions for guidance in the future search for oil and gas, from the facts already stated, it will be best to describe the principal remaining horizon of natural gas in the State, albeit it is not a horizon of high-pressure gas.

SECTION VI.—THE OHIO SHALE AS A SOURCE OF GAS AND OIL.

The two main sources of gas and oil in Ohio have now been described, and the approximate boundaries of their productive territory, as shown by recent explorations, have been pointed out. But what of the wide belt of country that lies between these boundaries in northern Ohio? Is it entirely destitute of oil and gas? Is it, by its composition and structure, debarred for all time from taking any part in this production?

It may seem like a contradiction after what has been claimed for other districts, and what has been denied at least by implication for this, to assert that within this intermediate area, or at least within those portions of it that lie nearest to the main Berea boundary, there is not only a greater number of gas springs, oil-seeps, and other surface indications than is to be found in any other equal area in the State, but a much larger number of gas wells in steady flow. But this statement can be fully substantiated without antagonizing the claims that have been made for the Berea grit and the Trenton limestone.

The belt of country to which reference is now made, it will be remembered, extends along the south shore of Lake Erie west-

ward from the Pennsylvania line as far as the Huron river, from which point it extends southward to the Ohio valley, with a breadth varying from fifteen to forty miles.

This belt takes in the western outcrop of the Ohio (black) shale, and also the outcrops of the Berea grit and its normal covers, extending eastward and southward until the sandstone has had time to fall 300 feet or more below the surface of the valleys. There must be added to it also 1,000 to 1,200 square miles in the north-western corner of the State where the Ohio shale is the surface rock, covered, however, as a rule, by heavy beds of drift.

The main territory thus bounded will be recognized by all conversant with the facts as embracing the most numerous and longest known gas wells of the State, those, namely, which have been drilled along the shore of Lake Erie, mainly between Cleveland and the Pennsylvania line. There is not a township between the limits named in which one or more successful wells has not been drilled. At many points, wells have been drilled to the number of six and more, which are yielding steady and excellent supplies. A few general statements will suffice as to the character of this supply:

1. The gas is of the same character as that found in the Berea grit. It is probably, however, more uniform and constant in composition than that which is yielded by the latter stratum from considerable depths. Its odor is not marked or offensive, and consequently good gas-fitting is required when it is introduced into domestic use.

2. It is, without exception, low-pressure gas. This term is relative, not absolute, it is true, and pockets of gas are often found in drilling, to which the statement would not apply, but when the wells have settled down to their normal flow, the closed pressure probably never rises as high as 100 lbs. to the inch.

3. The wells, in like manner, yield but comparatively small volumes. A daily yield of 80,000 feet is as high as has yet been measured. Wells with one-fourth of this production are counted good wells, and many of them range from one to 5,000 cubic feet per day. In some cases storage is effected by small gasometers that receive the gas as it rises and send it out with equable flow.

4. The supply from this source is peculiarly adapted to domestic use, and to this it is for the most part applied. The sharper

wells, however, are available for steam production and other like services. To make a really good illuminating gas, it would need to be enriched by a naptha bath, but, so far as known, this method has not been used. Street-lamps, yard-lamps, and house-lights supplied by the gas are all in common use where wells are in operation, but the main volume of the supply is for heating purposes. For cooking stoves and ranges, and for ordinary open grate fires, it is most happily adapted. The convenience resulting from its introduction for all such uses passes description.

5. The horizons of the gas in the shale have not yet been determined. At first sight the gas would seem to be capriciously distributed, but this appearance may be proved deceptive when more opportunities for observation have been furnished. There are always few, and often no recognizable horizons in the shale unless it is covered by the Bedford and Berea formations, and consequently it is difficult or impossible, without careful levelings from well to well, and accurate measurements of dip, a problem which is dependent on, and complicated by the same factors, to determine the relations of the gas-producing horizon, whether widely extended or sporadic. The wells that are now being sunk in the neighborhood of Berea will do much towards answering these questions, inasmuch as they generally pass through the Berea grit and Bedford shale, one or both, or at least stand in such relations to the outcrops of the sandstone, that measurements can be taken from it to the gas-producing beds. The difficulty in fixing upon horizons in the shale itself, and the entire inadmissibility of the old classification of the Ohio shale into Cleveland (black), Erie (greenish-blue), and Huron (black), are well shown in the record of the home well of Mr. A. W. Bishop, of Berea, which has been finished within the last year.

The record is as follows:

Drift beds....	Soil and clay..................	19 feet.	21 feet.
	Gravel	2 "	
Berea grit....			55 feet.
Bedford shale	Light-colored soapstone, soft....	15 feet.	124 feet.
	Hard sandrock.................	8 "	
	Light-colored soapstone, soft....	4 "	
	Red shale.....................	82 "	
	White slate....................	15 "	

Ohio shale.	Brown soapstone	55 feet.	1120 feet.
	Dark shale	20 "	
	Light-colored slate	350 "	
	Dark slate	155 "	
	White slate	30 "	
	Black shale	45 "	
	White soapstone	25 "	
	Black shale	35 "	
	Light soapstone	30 "	
	Black shale	30 "	
	Light soapstone	15 "	
	Black shale	30 "	
	Light soapstone	215 "	
	White shale, hard	15 "	
	Black shale	15 "	
	White shale, gas	20 "	
	Black shale	35 "	

Corniferous limestone struck at 1,320 feet and drilled into fifteen feet; total depth of well, 1,335 feet.

From the Berea grit to the Corniferous limestone, the interval here is 1,244 feet. Question may be raised as to the exact base of the Berea, however. The alternations of shale above noted, and the approximate thickness of the different elements, can be learned from the section; but the exact thickness of each element was not an object of curiosity on the part of the driller, and the facts are given in round numbers, as is obvious. The driller distinguished shale from soapstone in his record by the test of hardness. The plastic shales are called soapstones; the hardest and firmest shales at the other extreme in this respect make the slates of this record.

Gas was found in this well at 600 and at 775 feet, and also as noted in the record near the bottom of the shale, but the supply is in fact quite small, all of it being utilized in a single house without meeting even then all demands; but in other wells drilled within two or three miles, a much more vigorous supply has been reached, and at considerably less depth. Between 700 and 800 feet in depth the most prolific horizon was found at these other localities, and the best supplies came from a considerable range in the rock. As the drill descended, foot by foot, new supplies were released.

6. The influence of structure, or, in other words, of breaks or arches of the beds on the accumulation of gas in the Ohio shale

is presumably the same, as in the case of the reservoir that so often overlies it, viz: the Berea grit; but by reason of the same class of facts that obscures the problems of dip and gas horizons, the assertion that such is the case must be made in qualified terms. In a few examples, and notably in the Mastick well, in the valley of Rocky river, near Berea, a small but distinctly marked break in the shales occurs as a rudimentary anticlinal, the direction of which is N. 40° E. Along this break gas has always been escaping in considerable quantity. Salt water rises with the gas, the locality being one of the brine licks of early days. When the drill descended along the crown of this axis, gas was found all of the way down, but the chief supplies came at 400 and 500 feet. Two months after the well was drilled, its outflow was found by the anemometer to be 21,643 cubic feet per day. It apparently maintains this production to the present time.

While the shale is so charged with oil and gas that a dry hole drilled into it at any point would probably show some outflow of gas, still it seems probable from the facts of distribution of the larger wells that the same determining causes in minor structural disturbances that connect themselves with our other supplies, will be found here when proper opportunities for observation and study have been secured.

7. The gas yielded by the shale seems fairly persistent. General J. S. Casement's first well at Painesville was drilled sixteen years ago, and it still yields more than gas enough for ordinary household use. The gas springs of Fredonia, N. Y., have been used for illumination since 1821, and though the original supply has been disturbed by the drilling of wells within their area, there is no reason to doubt that it would have continued indefinitely if it had not been so disturbed. By the drilling of the wells referred to, the production of the original tract has been largely increased.

It seems probable that gas is constantly produced in the shales, not by the decomposition of the organic matter that they contain, a process which, so far as we know, can be effected only by destructive distillation, but by the simpler change of the petroleum with which the shales are everywhere charged into gaseous products. The theory of spontaneous distillation of petroleum from the organic matter of the shales has been already discarded,

but the process here suggested has considerable superficial resemblance to it.

The permanency of gas supplies in the various sandstone reservoirs is in most cases connected with the amount of salt water produced by the gas rock. If the supply of brine is considerable, the wells can, with difficulty, be maintained, and in only a few cases can the wells be left to themselves. In most cases they are maintained by unremitting care in removing the salt water as it accumulates. While brine is not wanting in the shale gas wells, it is by no means as troublesome an element as in the sandstone wells. There are very many cases where a well is drilled dry and remains dry permanently.

8. The value of the gas supply that is now under consideration has never been properly estimated by the districts within which it can be secured. By its character, it is mainly limited to household use, but, as has been shown, for this purpose it can scarcely be improved when found under favorable conditions. The wells required to reach it are easily drilled and cheaply equipped. They require but little casing, and sometimes none, their maintenance involves neither trouble nor expense, and their supplies are fairly maintained. There can be no question but that the shale gas wells outlast the high-pressure wells of the sandstone reservoirs.

The problem of using low-pressure gas in town supply, the sources being within the town, has already been solved with a measure of success in East Liverpool, and also in Fremont, but the Berea Pipe Line Company has undertaken to transport gas of this character from wells that are two or three miles distant. The result of this undertaking will be looked for with interest, and if it proves successful a new impulse will be given to the development of the shale gas field.

There are farms by the thousand throughout these areas in which gas can be found in ample quantity for household use, and where the supply can be reasonably assured, by the drilling of occasional new wells, for certainly a long term of years. Such farms may come to be valued as much for this as for other and more easily recognized resources.

A word needs to be said in regard to the area of Ohio shale that occupies three or four of the counties in the north-western

corner of the State. This formation represents only the lowest beds of the great shale series. Not more than 150 feet have been found in any section thus far reported. It is in almost all cases deeply covered with beds of drift, sand, gravel and bowlder clay being variously interstratified.

When penetrated by the drill, as in the wells that are sunk for water or more recently for gas, this shale stratum often sends out notable quantities of gas. The main supply seems to be derived from near the base of the shale.

Gas is also found frequently in the drift beds overlying the shale. There is another possible source for this supply, but it is quite likely that in some instances, gas from the shale has been accumulated in the gravel where the latter is covered with bowlder clay. All the conditions for gas accumulation seem to be met by this order of arrangement.

The stocks of gas in the north-western shales cannot be as large or as enduring as those already described in the shales of the eastern area, on account of the small thickness of the formation, but it may still be found that there are some accumulations that can be used with profit in the way of household supply. Persistent stocks of high-pressure gas are scarcely to be expected here.

SECTION VII.—THE CLINTON, MEDINA, HUDSON RIVER AND UTICA SHALES AS A SOURCE OF GAS.

Between the limit at which the Trenton limestone has thus far been found largely productive, viz: the line of 500 feet below the sea level, and the western boundary of the Ohio shale in its main outcrop, there is a number of counties, as Ottawa, Sandusky, Seneca, Wyandot, etc., with parts of others to the east of their respective boundaries, in which it seems hopeless in the light of all explorations made to the present date, to look for oil or gas in the Trenton limestone. The wells of Fremont and Carey have already been referred to, but since the previous statements in regard to them were put in type a few new facts as to their pro-

duction and character have been obtained. Three wells have been drilled at Carey, the first of which now yields by anemometer measure, 27,163 feet per day. The well shows a closed pressure of 405 lbs. The second well yields 21,375 feet per day. The third well appears at present to be a failure. The first and second both obtained notable supplies of shale gas. It was especially strong in the latter, but the present production is largely from the Trenton.

At Fremont, as previously stated, eight deep wells have been drilled. The best of these deep wells is well No. 2, of the Natural Gas Company. It yields by anemometer measure, 18,720 feet per day, and is used in the lines of the company. The best of the three shallow wells lately drilled in the town is the Ames well, the daily production of which is 16,473 feet. This well gets all of its gas from the Clinton limestone and shales, the Niagara shale making the cover. Wells directed to this horizon need not be more than 500 feet deep, and they can be drilled and equipped for less than $1,000. The discovery of this supply is of great importance in this part of the State.

A well has been brought in at Oak Harbor, Ottawa county, within the last few days, of much larger volume than any of those last described. Measured in the first week of its flow, it makes a record of 78,250 cubic feet per day. Its pressure rises to 101 lbs. when the well is closed forty minutes. The gas is derived mainly but not entirely from the Trenton, which was reached at a depth of 1,300 feet, or 724 feet below tide. The rock was shot with sixty quarts of nitro-glycerine. This well comes much nearer to being an exception to the 500-foot line already laid down, than any other in the field. If it maintains its flow, and if other wells of equal volume are found, a gas field of some importance will be established here. A little oil of 38½° gravity is found with the gas. The town is enterprising and the advantages of natural gas, if an adequate supply is reached, will be turned to the best account.

It has already been shown that low-pressure gas is available in some localities in the Clinton, Medina, and Hudson river shales. The experience of Fremont has demonstrated this fact, and it is a point of considerable importance. Wells can be drilled to this horizon in the western part of the area referred to, without great

expense. The gas found in the three wells drilled at Sidney is all derived from these shales. It has not proved persistent at this point, but a considerable volume was yielded by the second well. Two months or more after its completion its daily flow was found to be 39,744 feet. The supply is one that needs further investigation in this region.

As has been previously shown, there have been notable quantities of gas yielded throughout the Findlay district from these shales from the first development of this field. The 700-foot horizon at Findlay, has in particular, been found a vigorous source. In other fields, this alone would be counted a very successful supply. In the Briggs well, the upper vein is cased off separate from the Trenton gas, and the former has been found by measurement to exceed 200,000 cubic feet per day.

The "blowers" of gas struck at Springfield, Piqua, and at many other points, which have raised such extravagant, but short-lived expectations, all come from these sources.

It now appears as if south-western Ohio were mainly shut up to these rather feeble and uncertain sources.

On the western side of the general district now under consideration, through the counties in which the Corniferous limestone has its outcrops, viz: through parts of Erie, Seneca, Wyandot, Crawford, Marion, Delaware, and Franklin, and through those parts of Paulding, Henry, Wood, and Lucas counties, in which the same formation makes the surface rock, it is hard to see what sources of oil or gas are available. The Trenton limestone is found unproductive, and the Medina and Hudson river shales lie too low to allow their supply, which is at best so moderate and restricted, to be sought for with any promise of profitable returns. The entire series of Devonian and upper Silurian limestones would require to be cased in such wells, and the expense would be large.

The remaining horizons of gas and oil in the geological scale of the State, which are found mainly in the sandstone strata of the Carboniferous and Subcarboniferous ages, and notably in the Waverly and coal measure conglomerates must be passed without further mention here. There are no very important supplies at present derived from any of them, but in past years, the oil production of the Cow Run field, of Washington county, and of

other adjacent fields attained respectable proportions, and even now considerable oil is found in the upper sandstones of Macksburg, as has been previously stated.

One other source of gas, however, is so common and so misleading throughout three-fourths of the State, that a few words must be devoted to it here. It will be briefly discussed in the concluding section of this abstract.

SECTION VIII.—THE GLACIAL DRIFT AS A SOURCE OF NATURAL GAS.

Nearly three-fourths of Ohio are covered with the deposits of the drift, the most recent, but the most anomalous and perplexing of all of our geological formations. These deposits consist, 1, of bowlder clay, a tough, compact and mainly unstratified deposit, containing fragments of rocks, from the size of pebbles to blocks of many tons weight, derived from regions to the north of where they are found, and which are quite generally smoothed and striated in such a way as to show that they have been subjected to a violent abrading agency; 2, of gravel and sand, clean and distinct, in pocket-like deposits, or variously intermixed with clay and that are included in or covered by the deposits of bowlder clay; 3, of stratified beds of sand, gravel, and fine clay, that are obviously of later age than the bowlder clay, and that owe their arrangement to deposit in water.

These beds taken collectively are of considerable thickness, especially in the north-western portion of the State. The drilling that is now going forward is revealing to us as nothing else could do, the vast amount of these drift accumulations. It is not uncommon to find sections of drift seventy-five to one hundred feet thick before the bedded rock is reached, and measures of 150, 175 and 200 feet have been occasionally found. The most surprising section ever reported from the drift deposits of Ohio, has, however, recently been found at St. Paris, Champaign county, on the line of the Chicago, St. Louis & Pittsburgh railway (mention is made of it on page forty of this report, but before the bottom

of the deposit was reached.) This town has an elevation by railroad levels, of 1,237 feet above the sea. It is 353 feet higher than Piqua, and 195 feet higher than Urbana, the elevations being counted from the stations of the railroad above named.

In the well recently drilled at Urbana, the drift deposits were found 155 feet deep. The bedded rock is therefore here about 900 feet above sea level. At Piqua, the Miami river is running on rock at about 860 feet above the sea.

But the drillers at St. Paris found no bedded rock until they had driven pipe to 510 feet below the surface. In other words, the bedded rock here lies at 727 feet above the sea, or 140 feet lower than the rock at Urbana, and 170 feet below the present bed of the Miami at Piqua. This is, without doubt, by far the thickest bed of drift yet reported in this State. At 400 feet a considerable amount of vegetable matter, tree trunks and branches and black soil, was found. The wood is red cedar. "Mussel shells" were reported to be found with the wood, but no opportunity was found to verify this observation.

Attention was long ago called to the fact that the Miami river is running in a rocky channel most of the distance from Sidney to Dayton, and that this channel is therefore a recent one, worked out since the close of the glacial period. A part of its old channel in Clarke county was also pointed out, but though it was easy to see that the original valley was to be looked for to the eastward of its present course, no one would have dared to locate it under the highest ridge in all this part of the country. Yet it is just this which the drill has now demonstrated, and St. Paris is found to be situated directly above the ancient channel of the Miami river. Other points will undoubtedly be found in this buried channel by which its course can be determined.

The fact that vegetable matter in the shape of cedar wood was found included in the bowlder clay of St. Paris has been mentioned in the account above given. It is scarcely necessary to state that such material is of very common occurrence in the bowlder clay or just beneath it, on or near the surface of the bedded rock, in many portions of the drift-covered areas. These deposits often render the water which is associated with them foul and unfit for use. In some parts of the country they are known as "Noah's barn-yard." There are counties of Ohio in which a considerable

proportion of the wells that are dug strike this buried timber and these other accumulations of vegetable matter.

These facts are mentioned here to explain the origin of a large number of the "surface indications" of natural gas which are so attentively noted and so frequently reported at the present time.

This buried vegetation in a great number of instances gives rise to light carburetted hydrogen or marsh gas, which is the chief constituent of natural gas as well as of the fire-damp of coal mines. No line of division can be laid down between marsh gas, fire-damp, and natural gas. They are one and the same thing in substance. The gas escapes slowly from the drift beds, coming up with the water and giving rise to the weak gas springs that can be found so widely scattered through the State.

The gas is sometimes found in such quantity and with so steady a supply that it can be utilized for household service. It has been so used at a number of points in Champaign county, Illinois, for many years. The gas when enriched by passing through a naptha bath, is made available for household light as well as heat.

Surface indications of this sort are obviously of no value as guides to the great reservoirs of natural gas which our communities are seeking so earnestly at the present time. But it is the drift gas and the shale gas that are most frequently found and on which large expectations are often based. In other words, there are "surface indications" and "surface indications." Indications like those that Findlay gave from the date of its occupation to the discovery of high-pressure gas would no longer escape notice, now that it is seen what they stand for, but there are other points by the thousand in which only the weak outflow of gas escaping from vegetation which is slowly decaying without the access of the air, is to be noted, and these, as already stated, are without significance. The "surface indications" of the outcrop of the Ohio shale are also without significance so far as high-pressure gas is concerned. Small outflows are the rule rather than the exception throughout the whole extent of the outcrop of the black shale. To repeat what has been said already, natural gas is one of the common and widely distributed substances in nature, and a little of it at least can be found anywhere.

GENERAL SUMMARY.

In the preceding pages, it has been shown that there are two main areas of the State, involving distinct and widely separated geological horizons, in which high-pressure gas and large production of oil are now found. It has also been shown that there is another well-bounded and widely extended area in which low-pressure gas of excellent character and fairly persistent in its flow can be obtained. There are also two subsidiary areas of low-pressure gas, less developed and less extended, and of much less value.

These several areas can be shown in tabular form, thus:

High-pressure gas.	Berea grit territory. Trenton limestone territory.
Low-pressure gas.	Ohio shale, main outcrop. Ohio shale, north-western outcrop. Clinton, Medina and Hudson river shales.

1. The Berea grit territory occupies thirty-six counties of eastern Ohio in whole or in part, with the boundaries given on a preceding page. Through all of this area, the Berea grit is due at a depth of 300 to 2,000 feet below the surface. It is everywhere roofed with a thin bed of black Berea shale, which in turn is covered by 200 to 500 feet of the light-colored Cuyahoga shale. It everywhere overlies a great thickness of Bedford and Ohio shales, the former of which is often red, and the latter of which always carries a considerable proportion of dark or black bituminous shales, interstratified with light-colored bands. There is a wonderful uniformity in this entire series throughout the area named, as has been shown by a large amount of drilling. The productiveness of the Berea in oil and gas cannot, therefore, depend on the composition of the series, for in that case all would be productive. *It must depend on structure*, and in the few places where it has been found productive abnormal structure has been, in almost every instance, already detected.

The Berea grit is not the only petroliferous horizon in this area. The coal measure sandstones and the Waverly conglomerate sometimes yield oil and high-pressure gas, but all these must be passed before the Berea is reached.

The practical deduction from these facts must be emphasized. The Berea grit is the lowest horizon yet found in these counties in which gas or oil is held in quantity. *There is therefore no wisdom in going below it in the search.* If it is found barren or full of brine, there the drill should rest. The particular territory tested must be counted unproductive. It is especially impracticable to seek to reach the other great horizon of high-pressure gas, viz: the Trenton limestone within the Berea territory.

This has been attempted repeatedly within the last year with great outlay and with no valuable return, except in the way of geological information. The scheme is essentially impracticable. Beneath the Ohio shale, which ranges from 400 to 1,800 feet in thickness, is the great series of Devonian and Silurian limestones. This series ranges from 700 to 1,100 feet in thickness. It is full of salt and sulphur water which must be cased off. This requires casing from 1,000 to 2,000 feet deep. After the limestones are passed 800 to 1,200 feet of shales due, and there is thus far not a single fact to warrant the expectation that if the Trenton is reached it will hold any valuable contents. It was found to lose its important stócks as it sunk from 300 to 500 feet below the sea level, and now that it is 1,000 to 2,000 feet below, we have no warrant for expecting any value in it, *from any facts that yet appear.*

In the shales underlying the Berea, low-pressure gas can sometimes be obtained, but supplies of this character properly belong to shallow wells, and cannot be managed profitably where deep drilling is necessary. At all events, they are not of value enough to be sought by deep drilling.

In the thirty-six counties already indicated, there is nothing to warrant the sinking of a well below the level of the Berea grit. The scores of instances already in hand demonstrate this fact, and new examples are accumulating every day. Large outlays may be avoided in many wells already projected or begun, if this counsel is heeded.

Practically, the Trenton limestone is as effectually cut off from the Berea grit territory as the Berea grit is from the productive district of the Trenton limestone. In the latter case the stratum to be sought for is a half-mile in the air; in the former, it is a half-mile under ground.

Although this sandstone stratum has been weighed in the driller's balance and found wanting at a great number of places in the State, there is yet ample room for exploration, and the best of reason for believing that much more imprisoned power will sooner or later be released from its widely-extended store house.

2. The Trenton limestone has been found a source of very valuable stocks of oil and gas in three counties of the State, viz: Wood, Hancock, and Allen, and there is much reason to expect that Auglaize and Hardin, and possibly Shelby, Logan, and Champaign counties may prolong the productive belt southward. The north-western boundary seems already fairly well defined: the north-eastern boundary less so, by reason of the small wells at Fremont, Carey, and Oak Harbor. The southern boundary, *which has not yet passed the Allen county line*, will be looked for with great interest. The Trenton limestone shows, as far as developed, absolutely no such structural lines as are found in the Pennsylvania oil fields, and the recognition of such lines in the present state of our knowledge is a delusion, if not a snare. But as in all such cases, only the successes are remembered; the far more numerous failures pass out of sight. The Findlay break is the only pronounced line of structure yet apparent, and this bears north 14° west.

There has not been found thus far in the experience of the entire field the slightest advantage, so far as oil or gas is concerned, in drilling more than fifty feet into the Trenton limestone, and many thousands of dollars have been already spent in these tedious and profitless descents. More money is now being expended in the same way. It is not to the driller's interest to continue the work, as the chances for loss of tools are many, but the companies are generally unwilling to accept a foregone conclusion, and to recognize their venture as a losing one until they have made it more so.

3. The Ohio shale gas belt is the most reliable in its response to the drill of any of the districts named, but it promises only low-pressure wells. It must be taken for what it is. It is vain to seek the lower horizons through it. The expense of casing through the limestone would be too great for the gas that is produced at or near the Medina horizon if it could be found. All that has been said in regard to deep-lying Trenton under previous

heads, applies here without qualification. In other words, *each division of the State is limited to its own horizon.*

4. So far as can now be seen, there are large districts of Ohio, and especially its south-western quarter, where high-pressure gas does not exist. More trials will be required to settle the character of particular fields, but there is nothing to warrant exploration on the large scale.

CONCLUSION.

The facts pertaining to the supplies of petroleum and natural gas in the State as at present understood, has now been briefly summarized. Special attention has been devoted to the last named of these closely connected substances, on account of the great practical interest that is taken in it at the present time. The progressive nature of geological science is kept distinctly in mind in what has been presented, and the consequent provisional character of many of the conclusions that are drawn in such fields as this, but it has been deemed better to present the conclusions as they now appear, rather than to wait for a larger and more complete set of facts which would be gathered only by costly investigations, part of which can be well enough spared. By presenting these facts and conclusions at this time, it is hoped that much of the indiscriminate, enthusiastic and often ill-judged drilling of deep wells that is now going forward in the State will be checked, and that a calmer and more intelligent frame of mind will be brought to bear upon the search for these buried treasures. The prevailing state of mind in regard to this search is not a very reasonable one. To start the drill and sink it "deep enough" is the proper policy in the average judgment. By "deep enough" is generally meant 2000 feet or more. A railroad 100 miles in length, from a manufacturing center to a coal field, may prove a profitable investment to the company that builds it, but it would be irrational for another company, inspired by the success of the first, to expect that another road run out from the city at random or even on a "north-east line," if only 100 miles long, would prove equally remunerative. All depends on what it finds at its terminus in the way of profitable business. The aim has been in these pages to show what *is* "deep enough"

in the several districts of the State, and to suggest proper *termini* for the wells that are going down.

There is really no such haste in this search for oil and gas as many communities seem to think. These stocks of buried heat and power have been for many thousands of years where they are, and substantially what they are, and they will remain available for thousands of years to come if left undisturbed. They will be worth more in coming years than they are now. They are safe in their present reservoirs. At least they cannot be drawn upon by drilling down at any great distances. It is a crime against the State to unlock them before any use is provided for their contents.

The conservative tone of this abstract, it is well understood, will not be as acceptable as a more hopeful view would be, for people like to be advised to do what they have made up their minds to do, but "the facts are what they are." What good can come to us from shutting our eyes to them?

Explorations should go forward on many sides, but cautiously and economically, and with an intelligent recognition of the conditions of the problem, and above all, its burdens should be properly distributed.

It will be borne in mind that this paper is an abstract of more extended discussions of the several subjects herein considered, which are to be presented with other material to the Legislature, on February 1st, 1887, under the title of Volume VI, Geology of Ohio. All errors of statement that are found herein can be corrected in a more deliberate publication that is to follow, and the conclusions drawn from the work already done will then be confirmed, extended, modified or set aside by the much wider series of facts that are coming into our possession.

APPENDIX.

MEASUREMENT OF THE FLOW OF GAS WELLS.

The determination of the amount of gas yielded by vigorous wells is a problem that has not hitherto been adequately solved. No methods at least have been found to be in common use at the centers of gas production, except vague and uncertain calculations based upon the pressure when the well is closed for a given period. The fallacy of this method has already been exposed. All wells of a district, great and small, attain, finally, the same closed pressure. The fact that wherever high-pressure gas is obtained at all, there is generally a surplus, probably accounts for the neglect of this question hitherto, on the part of those who control the large supplies. Nice measurements have thus far been superfluous, and, in fact, gas has not been thought of by definite volume, but only by the work it will do.

It is easy to see, however, that accurate knowledge of the yield of a well is essential to an economical disposition of its products. As the use of gas in the main fields is extended, and as the supplies begin to weaken, the question of quantity will speedily become more important, and all wasteful methods of supply that may now be in force will be discarded.

The problem of gas well measurement has been taken up by the Ohio Survey, and a method has been devised and worked out by Professor S. W. Robinson, of the Ohio State University, which is simple, easy of application and adapted to wells of every grade, the strongest as well as the weakest.

Space does not suffice to present the method here. An abstract of the chapter prepared for the Survey is to be published in the August number of Van Nostrand's Engineering Journal, and a briefer summary has already appeared in the American Manufacturer. Only the practical application of the method can be given at this point, and this but in part.

To measure the flow of a vigorous well, attach an open tube,

of convenient length, straight or bent, to a steam gauge. Hold the open end in the current of gas at the well-head in the line of flow, and note the pressure which the gauge shows in pounds. Add to this pressure 14.6, and divide the sum by 14.6, find the resulting number or that nearest to it in table I. Take from table II the number corresponding, increasing or decreasing proportinately to difference between number obtained by division and number in table I. Multiply the number thus found in table II by 3103, and the result will be the *velocity* of the current in feet per second. To find the *volume* per second, multiply the velocity (in feet) by the area of the pipe (in feet), and to find the volume per day, multiply this result (volume per second) by 86,400 (number of seconds in day of 24 hours). The result will be the volume at a temperature of 60° F., and at atmospheric pressure. Calculations can readily be made for different temperatures.

The tables I and II are given below:

I.	II.	I.	II.
1,035	.1000	1,572	.3742
1,071	.1414	1,620	.3873
1,107	.1732	1,669	.4000
1,145	.2000	1,719	.4132
1,183	.2236	1,770	.4243
1,122	.2449	1,822	.4359
1,263	.2646	1,876	.4472
1,304	.2848	1,930	.4585
1,346	.3000	1,986	.4690
1,389	.3162	2,043	.4796
1,433	.3317	2,101	.4899
1,478	.3464	2,160	.5000
1,525	.3606		

An example will make the mode of application clear:

The pressure noted in the gauge applied to a gas well is thirteen pounds. 13 + 14.6 = 27.6; 27.6 ÷ 14.6 = 1,889. The number nearest this in table I is 1,876, and the difference between this and the number found by division is .013, which is one-fourth of the difference between 1,876 and the next higher number. In table II, the number corresponding to 1,876 is .4472. The difference between .4472 and the number next above it is .0113. Add

one-fourth of this difference, or .0028 to .4472, the sum is .4500. Multiply .4500 by 3,103; the product is 1,396.35, which is the velocity of the gas in feet per second. The gas is escaping from a 5⅝-inch casing, the area of which is .1725 of a square foot. The daily yield of the well, therefore, is $1,396.35 \times .1725 \times 86,400 = 20,803,168$ cubic feet of gas at 60° F.

This method is applicable, with modifications, to smaller wells, but in wells yielding less than 1,000,000 cubic feet per day, the anemometer is much the most convenient instrument. The use of this instrument for this purpose was first suggested, so far as is known, by E. McMillen, Esq., of Columbus, and was first applied by him to the measurement of the Adams well in Findlay, in June, 1885. The measurements obtained by this instrument have been compared with other measurements, and their reliability is established.

The large gas wells speak for themselves, and in regard to their value when fortunately located there can be no question if they prove moderately lasting, but there is often no ready means of judging whether or not a small well is really making a proper return for the money spent in getting it. Measurements of daily flow, like those already provided for, furnish the only intelligent basis for settling such questions.

But even when quantity is determined, we need to know how to interpret the figures, or in other words, we need to know what 5,000 or 10,000 feet of gas will do in heating and lighting, or in making steam. This subject will be treated more fully in the final report, but a few suggestions will be offered here.

Wells drilled for home supply need not be considered at this time. Natural gas in such cases is counted a luxury, and is paid for on that basis, if necessary, but when a well is drilled for town or village use or for manufacturing purposes, how large a production must it make to be a safe investment? There are various elements involved—the cost of the wells, the outlay for distribution, and the price at which the gas can be sold. The probable life of the wells must also be taken into the account. A well ought to return the money spent on it, with proper interest, in the course of a very few years. The expenses of the distributing plant, with interest thereon, must also be covered in a reasonable period.

The open flow of the well cannot, of course, all be counted available for use. The amount will be materially reduced by friction in the pipes. Probably it will be necessary to allow 1,000 cubic feet at the well-head to every stove. The highest charge now made in the State for stoves is $3.00 a month, which is about ten cents per 1,000 cubic feet. A well yielding 25,000 cubic feet per day would thus pay $75 a month, or $900 a year. If the cost of the well is less than $2,000, such a return would probably be safe. The well would in this case return the money spent in drilling it, with proper interest, in the course of three years, and it would also bear its share of the expense of distribution. Perhaps wells of this grade are as small as can be made safely remunerative for town supply. Single wells of such volume cannot be depended on for steam production to be used in driving large engines. Wells of 40,000 to 50,000 cubic feet, or aggregating this amount, would be as small as it would be safe to rely upon for such use where no great distance is to be traversed by the gas.

Approximate lower limits for profitable production may be found in the facts here given. With the strong desire to succeed in the novel search, most of the newly formed gas companies satisfy themselves for a time, at least, with returns which they would be willing to accept in no other line of investments.

SUPPLEMENT

TO

PRELIMINARY REPORT

(PUBLISHED IN 1886)

ON

Petroleum and Inflammable Gas

BY

EDWARD ORTON,

STATE GEOLOGIST.

April, 1887.

NATURAL GAS AND PETROLEUM.

SUPPLEMENT

TO PRELIMINARY REPORT OF 1886.

By EDWARD ORTON, STATE GEOLOGIST.

During the interval since the first edition of this Report appeared, great progress has been made in our knowledge of the rocks of Ohio. The extreme activity in drilling deep wells that has prevailed in all portions of the State, and especially in western Ohio during 1886, will make this year always memorable in the history of our geology. The explorations of no single year hereafter can make additions of equal value to our knowledge of the stratigraphical order of the State. The leading facts have now been discovered and established; and we know the order from 1,000 to 2,000 feet below the surface in every portion of the State as well as we do the order of the strata that make the surface. Details of great interest and importance will remain to be added as long as study shall be directed to these subjects; but the main features of our under-ground geology are as well established by the drilling of 1886 as were the main features of our geological scale by Newberry's Survey of 1869–73. A number of the facts brought out by the explorations of the last year will be here stated. They pertain to the geological scale of the State, to the geological struc-

ture, and to the practical development of our several oil and gas horizons. The subjects will be treated under the heads above named.

SECTION I. GEOLOGICAL SCALE.

Some of the facts brought to light by the investigations referred to will here be given. They are in reality corrections of statements made in the first edition of this report.

1. *The Trenton Limestone.*

In the Preliminary Report it was stated that this great limestone, that has suddenly acquired such immense and almost incredible economic importance, nowhere reaches the surface within the limits of Ohio. This statement is probably erroneous. It now seems most reasonable to believe that the Point Pleasant quarries, of Clermont county, constitute the uppermost beds of the Trenton limestone. If this be the true reference of these well-known beds, they form the only outcrop of the stratum in Ohio. There are not more than twenty-five to fifty feet, at most, of these beds exposed above low water mark in the Ohio river. The Point Pleasant beds have long been known as the lowest rocks in the Ohio scale. By some geologists they have heretofore been counted the Trenton limestone. Mr. S. A. Miller, of Cincinnati, was the first geologist, so far as known, to assert this identity. In the pages of early numbers of the Journal of the Natural History of Cincinnati he announced this view (1879). Mr. W. M. Linney, of the Kentucky Geological Survey, has also asserted this identity. (See Report on Rocks of Eastern Kentucky, p. 6, 1882.) The stratum in this case had been traced northward from its well-known outcrop in the valley of the Kentucky river. The validity of this view has been approximately established by the facts derived from the records of the deep wells which have been drilled in western Ohio in such numbers during the last year. The rate at which

the Trenton limestone was found to be rising to the southward was such as would bring it to the surface at or about this point.

2. *The Utica Shale.*

The explorations of 1886 seem to show that the Utica shale fails to reach the Ohio valley. It has heretofore been believed to be represented in the lowermost beds at Cincinnati, the evidence being the presence of certain fossils of Utica age, none of which, however, are strictly diagnostic of this formation. In northern Ohio, it will be remembered, the Utica shale is found in normal thickness and color; and, moreover, it there contains its most characteristic fossils. The 300 feet of black shale underlying the Hudson river shale and overlying the Trenton limestone in the deep wells of Hancock and Allen counties, are unmistakably and unequivocally the Utica shale of New York. This stratum was followed with perfect distinctness and with definite boundaries southward from this region as far as Springfield; but, in tracking it further, it was found to rapidly lose thickness. At Dayton it is notably thinner than at Springfield; at Middletown it is but 100 feet thick, and at Hamilton but thirty-seven feet thick. The drillers who had followed the stratum from its normal sections in northern Ohio to the southward were the first to note and report this unexpected fact. It may, perhaps, be held that the formation has changed in composition and color in coming to the southward without, howover, losing its identity. This view does not seem to harmonize with the facts upon record. At the northward it is directly overlain by the well characterized greenish-blue beds of the Hudson river series. The lowest beds at Cincinnati, which have been by some referred to the Utica horizon, agree in lithological character entirely with these northern beds. So far as can be judged from the drillings, the Utica at the northward is never highly fossiliferous, like the Hudson river shale. From all the facts now in hand, it would appear that the Utica shale is lost in the Ohio val-

ley by overlap of the Hudson river shale which here comes down directly upon the Trenton limestone.

In the Findlay field, the Medina, Hudson river, and Utica shales have a combined thickness of about 800 feet. At Lima and Bowling Green the thickness is very nearly the same as at Findlay; but as these shale formations are followed westward toward the Indiana boundary, there is a notable reduction in their volume. At Defiance, we find the same interval but 610 feet in thickness; at Bryan, 665 feet; at Hicksville, 624 feet; while beyond the State line, still smaller measures are sometimes reported. To the eastward, the shale series slowly expands. At Tiffin, the thickness has become 930 feet; and at Sandusky, 1,030 feet, if the record of this well is correctly given. It is also to be noted that there are less distinct boundaries for the several divisions as we go westward. At Greenville, Darke county, for example, the driller reports the entire series as black shale. While the series scarcely deserves such a classification, it is certainly true that the Hudson river shale is darker than usual, as judged from the samples of drillings furnished, and that it thus approaches nearer to the normal color of the Utica shale. No additional statements are required for the next element in the geological column, namely, the Hudson river shale.

3. *The Medina Shale.*

The Medina shale, in the Findlay field, consists of two divisions—a blue bed from thirty to fifty feet in thickness—underneath which a bed of red shale of about equal volume is found. In western Ohio, the red color is mainly lost; and no record has yet been seen of the occurrence of red shale at this horizon in Indiana. To the eastward, the entire formation is often found to be red shale. Its volume is also expanded in that direction, until we find no less than 200 feet that must be referred to this division. It is possible that it wedges out altogether to the westward. In

southern Ohio it is reduced to fifteen feet in some sections in outcrop.

4. *The Clinton Group.*

In central Ohio more or less shale is found interstratified with the Clinton formation, and the series is correspondingly increased in thickness thereby. This appears in the Sandusky, Columbus and Lancaster sections, and is especially prominent in the last named instance. There are 150 to 200 feet of beds that must be referred to this division in this well. In the Clinton thus strengthened there are numerous beds calcareous in composition and red in color. In the Lancaster well there were reported by the driller at one point thirty feet of red rock which, on examination, proved to be unmistakable Clinton ore, which is also known in the several States in which it occurs as the fossil ore, the dye-stone ore, and the flax-seed ore. Wherever this Clinton ore occurs, its presence renders unnecessary any further discussion of the geological place of the stratum that contains it. There is not, in the geological scale of the United States, a more unique or distinctly characterized deposit than this same Clinton ore. It will be borne in mind that the ore also appears in outcrop in Clinton, Highland and Adams counties of southern Ohio.

5. *The Niagara Group.*

The Niagara shale strengthens to the eastward apparently. It is eighty feet thick at Newark, according to the record of the deep well recently drilled here. It is distinctly characterized almost everywhere. In the Findlay field the wells are sometimes cased in this formation, but never with entire safety, since salt water is likely to be found in the Clinton group below it.

The Niagara limestone has a maximum thickness of about 200 feet; and in many instances is quite easily distinguished from the Waterlime or Lower Helderberg limestone which directly overlies it, by its color, which is gray or blue, and thus distinctly

contrasted with the brown color of the latter. These colors are not, however, constant and it is generally impossible to establish sharp boundaries underground on this basis.

6. *The Waterlime or Lower Helderberg Limestone.*

The facts developed by the drill in regard to this formation are entirely unexpected. It has been found to have a maximum thickness equal to the combined thickness of all the other limestones with which it is associated. The breadth of its outcrop ought to have shown us that there was a greater body of it than we had provided for in our sections; but heretofore it has been supposed that we were dealing fairly in assigning to it a total thickness of 100 feet. Instead of that, we are now sure that it has a thickness of at least 500 feet, and very likely a maximum thickness of 600 feet. The "Salina Group," as it now appears, is to be absorbed in it and must disappear from the scale, so far as any series in Ohio geology having a distinct boundary is concerned. *The plaster beds of Gypsum and of the islands of Lake Erie, which have been heretofore referred to the Salina Group, belong at about the middle of this great series.* In some well records, gypsum is found distributed abundantly through 200 feet of strata, with single beds having a thickness of six or seven feet. Gypsum, or anhydrite, is found in almost every well record in northern Ohio where a full set of drillings has been preserved.

There is a great deal more to be learned about the Waterlime or Lower Helderberg limestone in its outcrops in the State as well as under cover; but the important facts now brought out for the first time will greatly aid in the future study of this important division.

Another surprising statement must be added to the account already given of the Lower Helderberg series in Ohio.

To it belong the Sylvania and Monclova sandstones. These anomalous and important deposits have been heretofore assigned

to the Oriskany horizon, but they are at least 200 feet below the Oriskany. The Sylvania sandstone is directly overlain by 200 or more feet of unequivocal Waterlime beds. The Monclova sandstone is also found covered by the same limestone, but no opportunity has been found for determining the thickness of the overlying beds in this case. This particular sandstone deposit is doubtless sporadic in its distribution, but it seems to hold to its horizon after all. With but little doubt, the Sylvania sandstone is identical with the thirty feet of sandstone found at a depth of about 2000 feet in the perplexing record of the Cleveland Rolling Mill well.

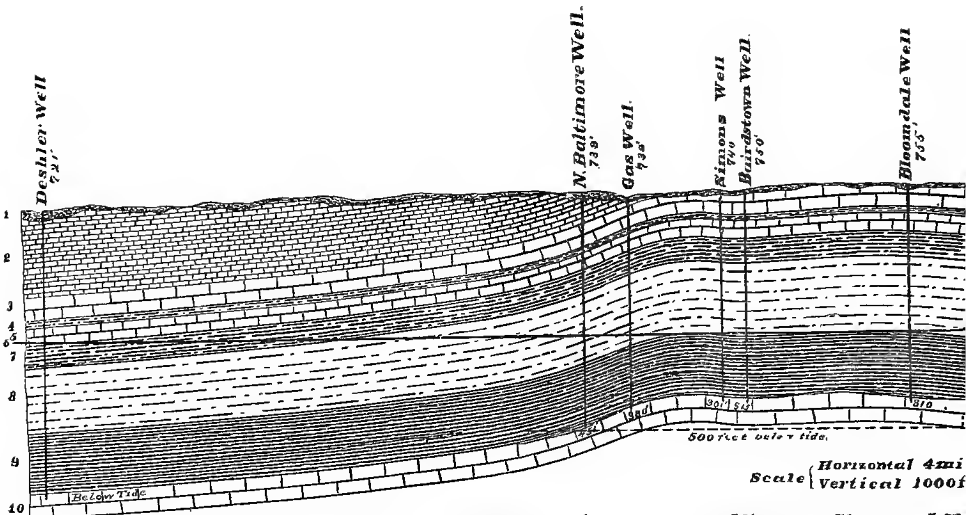
7. *The Upper Helderberg Limestone.*

This important limestone, usually known in Ohio geology as the Corniferous limestone, nowhere attains a greater thickness than seventy-five feet in the column of the State. This thickness it reaches in Delaware and Franklin counties. It begins as a magnesian limestone, but still containing abundant and characteristic fossils. The carbonate of lime increases quite rapidly as we rise in the series. The main heavy bedded building stone division carries but seventy per cent. of carbonate of lime, while the upper division equals or exceeds ninety per cent. It is found that the different limestones of our scale can in many cases be positively identified by the drillings which are brought up from whatever depth. The Corniferous, at least, can be sharply distinguished from the Waterlime and the Clinton from the Niagara, by means of analysis.

The Oriskany sandstone disappears from the Ohio scale. There is a sharp sandstone imbedded at several points in the Upper Helderberg limestone, it is true, but there is no good reason for calling this the Oriskany sandstone. It was deposited a long while after the Upper Helderberg limestone was begun, so far as absolute measure of time is concerned. It is comparable in all respects with the Hillsborough sandstone and also with the Sylvania sand stone just described.

Thickness of the Devonian and Upper Silurian Limestones.

The thickness of the combined limestone series of the State in whole or in part, is a very important fact in drilling wells for oil or gas, as it determines the amount of casing required by the wells. The thickness of these upper limestones is shown in the following table. In regard to these measurements, it must be confessed that they are not in all cases exact. The Clinton group, when shaly, is often cut off from the bottom of the limestone column by the drillers, the casing being placed in the Niagara shale. In many of the measurements given herein, samples of drilling have helped to determine the boundaries. Generalizations are not needed in regard to these figures at this time. In the following named towns, the entire thickness of the limestones was passed through, viz: Bryan, Bucyrus, Crestline, Delta, Defiance, Hicksville, Lancaster, Newark, Napoleon, Plymouth, Sandusky, and Wauseon. Bloomington and Columbus also take in almost the whole series. The asterisk indicates an unfinished section of the limestones, and the interrogation point occurs where boundaries are more or less indistinct. It is understood that in all of these records, where the whole thickness of the limestone is found, there is a cap or cover of the Ohio shale and of drift deposits of varying amounts.

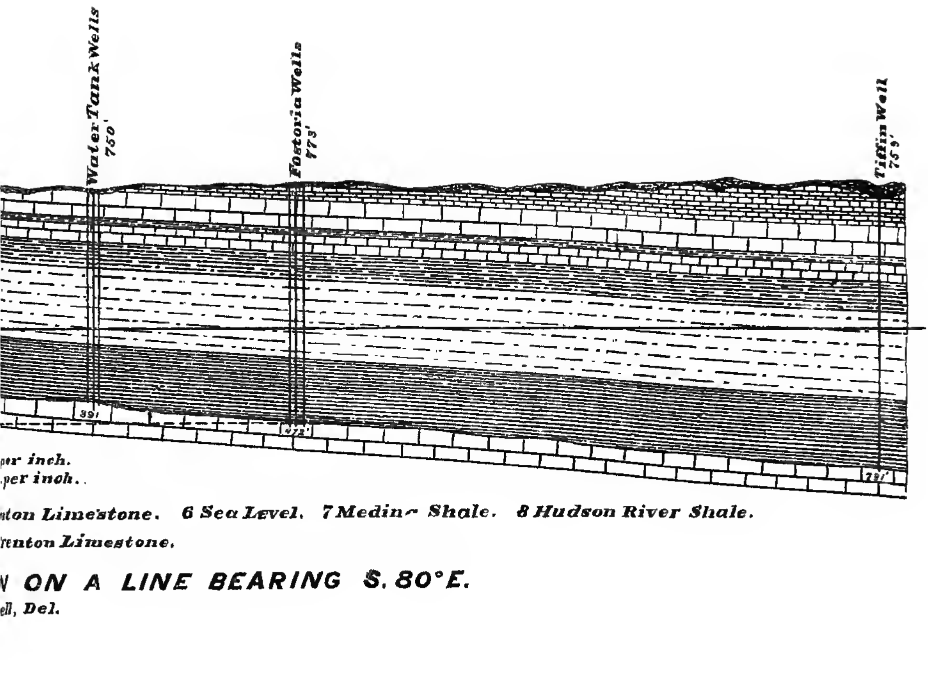


1 Drift. 2 Lower Helderberg. 3 Niagara Limestone. 4 Niagara Shale. 5 Cli

9 Utica Shale. 10 T

SECTION FROM DESHLER TO TIFFI

M.R. Camp



per inch.
per inch..

nton Limestone. 6 Sea Level. 7 Medin~ Shale. 8 Hudson River Shale.
Trenton Limestone.

N ON A LINE BEARING S. 80°E.
ell, Del.

Belle Center	340	Hicksville	928
Bellefontaine	635	Kenton	400
Bellevue	1000*	Lancaster	700?
Bloomville	840	Lima	350
Bowling Green	345	Marion	615
Bryan	1009	Magnetic Springs	354
Bucyrus	816	Napoleon	966
Carey	257	Newark	1050?
Celina	193	Oak Harbor	371
Clyde	850?	Ottawa	530
Columbus	726	Plymouth	1050
Crestline	857	Sandusky	1170
Delta	1132	Springfield	100
Defiance	960	St. Henry's	110
Deshler	710	St. Mary's	194
Eaton	40	Tiffin	560
Elmore	410	Urbana	123
Findlay	250 400	Union City	180
		Vanlue	215
Fostoria	400	Washington C. H.	190
Fremont	360	Wauseon	1100?
Green Springs	485	Weston	648
Greenville	260		

8. *The Ohio Shale.*

Much important information has been gained during the last year in regard to the great shale series of eastern Ohio. It has been pierced and gauged at many points; and at others where the drill has failed to penetrate it entirely, we have still obtained measures which show a very great volume without giving us a complete section. But data of this last named sort have taught that in the upper Ohio valley the shales exceed 2,600 feet in thickness, such a measure being reported from Wellsville without exhausting the shale. It has the least thickness in southern Ohio. In Highland and Adams counties, the interval between the Berea grit and the Upper Silurian limestones is reduced to 250 feet. At Lancaster,

the interval between the Berea grit and the Upper Helderberg limestone, which appears in this section and not in the one first named, is 650 feet; at Newark, 890 feet; at Mt. Vernon, 1,174 feet; at Mansfield, 640 feet; at Plymouth, 648 feet; at Berea, 1,250 feet; at Cleveland, about 1,400 feet; at Massillon, 1,800 feet; at Akron, 1,860 feet; at Canton, a somewhat greater measure, and also at Canal Dover; at East Liverpool, it exceeds 2,400 feet; at Wellsville, it exceeds 2,600 feet. In regard to this list, it may be added that the figures given for Mt. Vernon are much in excess of the other points along the line. These figures were given by the driller of a well at this point two years ago. A more recent record has been made, but it is not now at hand.

The great importance of these facts in relation to the supply of oil and gas through eastern Ohio will not escape attention. When the drill passes, in its descent, the Berea grit, it enters upon this great shale series in which low-pressure gas is contained, if any. The impracticability of drilling through the shales to the underlying strata is plain, from the fact that the great body of limestones usually found next below always carries salt water, and this fact would require the casing to extend to the bottom or nearly to the bottom of the series, a demand which it is impracticable to fulfill. The crowning reason remains, however, to be added. Nothing worth going down for has been found at these great depths in our series in a single instance. The discoveries pertaining to the Berea grit will be characterized in another connection.

SECTION II.—GEOLOGICAL STRUCTURE OF OHIO.

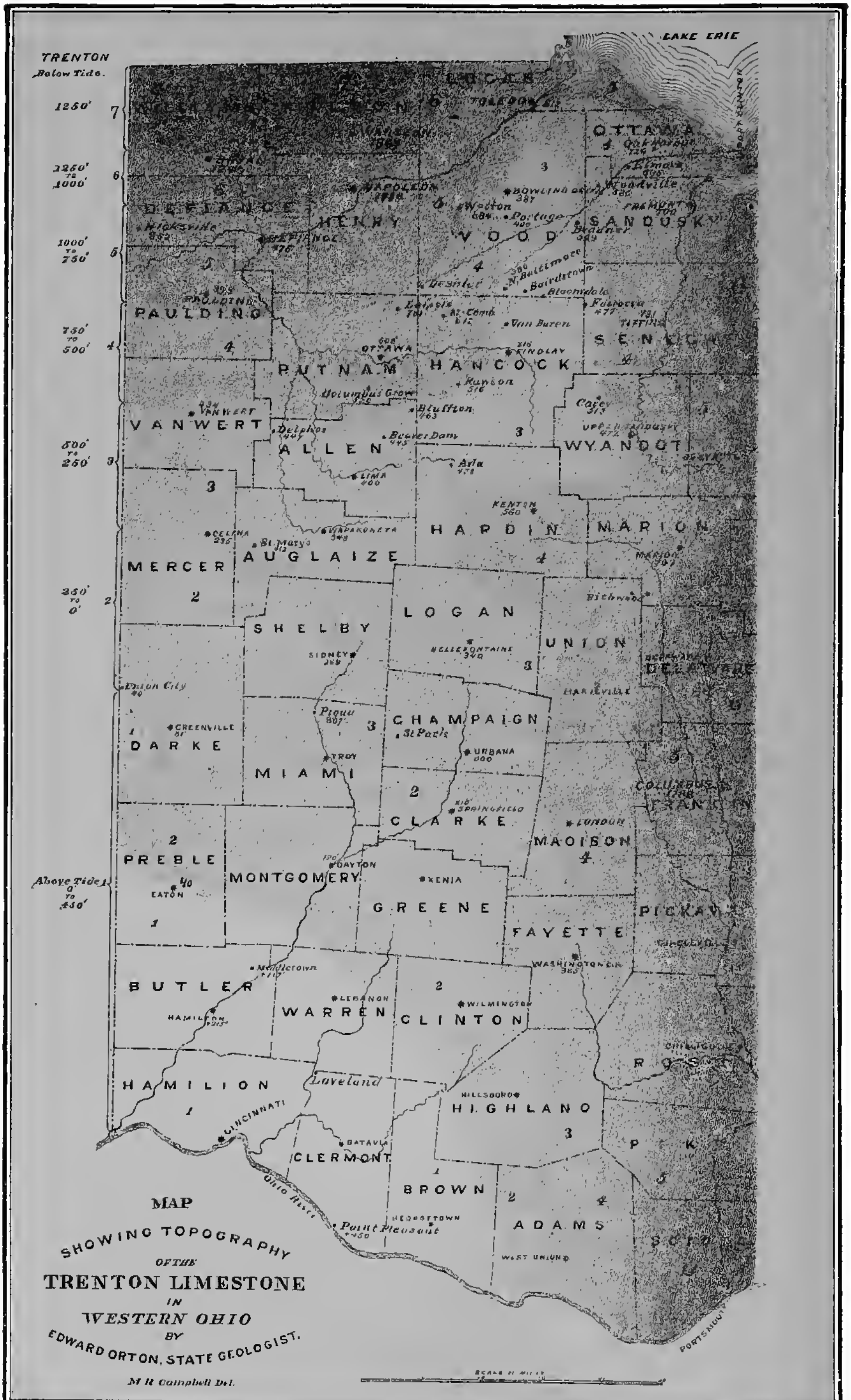
The Cincinnati Axis.

The facts pertaining to this section of the Preliminary Report that have accumulated during the last year are full of importance and interest. The most striking of them pertain to the so-called

Cincinnati axis. By the explorations that have gone forward, it has been possible to obtain a large series of facts which give us a much clearer idea of this ancient uplift than we could ever have secured without them. The fortunes of this great factor in our geology are bound up with the Trenton limestone and must be studied with reference to its history and conditions. A part of what we have heretofore counted the results and exhibition of the uplift is found to be due to an entirely different cause, namely, to the thickening of the lower formations in certain areas. All the essential features of this uplift must be found in the disposition and arrangement of the Trenton limestone. The Trenton limestone *is* the Cincinnati uplift. On the map on following page the topography of this great stratum in western Ohio is indicated by a series of shadings that present the facts in a graphic manner to the eye. The map requires no special explanation. In southwestern Ohio it is seen that there is a considerable area in which the Trenton limestone lies above tide water. This area is left unshaded. In the rest of the territory represented, the descent of the Trenton to lower levels is marked by shading and numbers, each of which stand for 250 feet of descent. Thus, the belt marked 2 indicates that portion of the State in which the Trenton limestone lies between tide level and 250 feet below tide level. Division 3 indicates all those parts of western Ohio in which the Trenton limestone is found between 250 and 500 feet below tide, and so on.

A study of the map reveals a number of unexpected and surprising features.

1. The Cincinnati axis bears to the north-west instead of to the north-east, as has been heretofore held. The highest level of the limestone passes from Point Pleasant, where it is about 470 feet above tide, through Clermont, Butler and Preble counties into Indiana, where it seems to be continued in a broad tract, the western boundary of which coincides in a general way with the


LAKE ERIE
TRENTON
Below Tide.
Above Tide
LUCAS
OTTAWA
DEFIANCE
HENRY
WOOD
SANDUSKY
PAULDING
PUTNAM
HANCOCK
SENECA
VANWERT
ALLEN
WYANDOT
MERCER
AUGLAIZE
HARDIN
MARION
SHELBY
LOGAN
UNION
DARKE
MIAMI
CHAMPAIGN
CLARKE
MADISON
PREBLE
MONTGOMERY
GREENE
FAYETTE
BUTLER
WARREN
CLINTON
HAMILTON
HIGHLAND
CLERMONT
BROWN
ADAMS
MAP
SHOWING TOPOGRAPHY
OF THE
TRENTON LIMESTONE
IN
WESTERN OHIO
BY
EDWARD ORTON, STATE GEOLOGIST.
M R Campbell Del.

western boundary of the Upper Silurian rocks of the State. The limestone maintains itself above sea level as far to the north-west as Eaton and Muncie, Delaware county. These facts seem to justify us in saying that the Cincinnati axis bears to the north-west instead of to the north-east as it leaves south-western Ohio.

2. From this high-lying tract of the Trenton limestone there is a north-easterly prolongation or off-shoot, that enters Ohio from Indiana, in Mercer county, and passes thence through Auglaize, Allen and Hancock counties. This has proved itself to be one of the most important divisions of the formation in north-western Ohio and it may well be named the *Lima axis*

3. From the central part of Hancock county, the line of highest levels of the Trenton limestone bears nearly due north, but with a small westerly element appearing in its direction. This tract is bounded on its west side by the most remarkable structural feature yet developed in Ohio geology. It consists of a pronounced monoclinal fold, the descent of which is nearly 200 feet. The monoclinal passes directly through Findlay, and was first revealed in connection with the gas and oil wells of that town. It may well be styled the *Findlay Break* or the *Findlay Monocline*. The Trenton limestone, on the east side of Main street, in Findlay, at a depth of 1,100 feet, is found in a flat-lying tract or terrace, the upper surface of which is a little more than 300 feet below tide water. From this level the limestone descends to the west quite abruptly, falling 120 feet in 1,000 of horizontal measure, in at least one well known instance.

The Findlay break has not been proved to be strictly continuous to the northward, but even if there is no single monoclinal that traverses the rocks there is, at least, a succession of such breaks with a general northerly direction that extends to the Michigan line. Van Buren, Portage, Bowling Green, Monclova, and Sylvania are all on the edge of steep descents to the westward. The great gas wells are mainly located upon the eastern margin of

the slopes, and their extraordinary production is explicable to an extent by the facts of their location. Reference will again be made on a later page to the continuation of the break.

The Trenton limestone is developing great value as a source of gas in Indiana, and the facts there obtained need to be correlated with the original series in Ohio before the full significance of either can be understood. The levels of a few Indiana wells, with reference to tide water, are here given, as reported by Dr. A. J. Phinney, of Muncie, Indiana:

Connersville	127	feet	above	tide.
Richmond	64	"	"	"
Winchester	24	"	"	"
Muncie	64	"	"	"
Eaton	5	"	"	"
Portland	71	feet	below	tide.
Bluffton	215	"	"	"
Decatur	460	"	"	"
Ft. Wayne	643	"	"	"
Kokomo	86	"	"	"
Tipton	129	"	"	"
Indianapolis	820	"	"	"

In eastern Ohio little has been added to our knowledge of the arrangement or structure of the strata. The confirmed monotony from which it has long been known that this portion of the State is suffering, so far as gas and oil production is concerned, comes out into continually clearer light as more work is done in the field. The folds are very few in number, but their numbers, after all, exceed their value. They seem in large parts of this territory too low to insure the effective concentration which oil and gas production require. This point will be considered somewhat further on a later page.

SECTION III.—THE DEVELOPMENT OF THE OIL AND GAS TERRITORY.

Astonishing progress is to be reported in the oil and gas fields of Ohio and Indiana within the last year. The results are far beyond any sober or conservative estimates that could have been made in the spring of 1886. In fact, it is hard to appreciate the reality of what is passing before our eyes.

I.—GAS PRODUCTION.

(a). FINDLAY FIELD.

The Findlay gas field still remains by far the most important center for the utilization of the new found fuel. The development of manufacturing industries at this point is without precedent in the history of Ohio towns. The population of Findlay has been more than doubled within the last year and will be doubled yet again in 1887, and the price of real estate has been multiplied, it is safe to say, if present rates are any gauge, many times; and for the last few weeks a strong current of speculative excitement has been sweeping through the entire region. Capitalists are gathering in from all quarters, and investments are being made on a very large scale. Large and varied manufacturing interests are prominently represented in these investments; and it is certain that the developments of the last year will be found to be insignificant in comparison with what 1887 will have to show. The geological structure of the Findlay field has come clearly into view by the drilling that has already been done in it. The essential features of this structure were clearly apprehended a year ago; and the statements that were then made in regard to it need no correction nor qualification at the present time: but the developments of the

year have given new significance to the surprising discovery that was then announced to the effect that a monoclinal fold with a down-throw of 200 feet crossed the town in a direction nearly north but with a small westerly element. A monocline, it may be stated in passing, consists of two terraces or level tracts of a single stratum connected by a steep slope. The Findlay break extends many miles to the northward, as has been already stated, and probably to the southward also. It has not been as distinctly traced to the southward as in the other direction, for lack of time to devote to such field work; but enough facts have been already obtained to render it probable that there is a continuation of the abrupt descent of the rocks in the territory to the south-east of Findlay, the sharpest descent extending through the center of Jackson township and along the eastern line of sections of Delaware township, passing within a mile of Forest. It is, perhaps, continued still further south through Jackson and Goshen townships of Hardin county. Northward, however, the line of the break is much clearer. It does not prove to be represented by a strictly continuous geological formation, but a few sags appear in it at various points. Barring these depressions, however, it can be said that a line of broken structure extends from Findlay to the Michigan border, which it reaches about two miles west of Sylvania. The break is quite as pronounced at this point as at Findlay. The descent to the westward is at least 200 feet in less than a quarter of a mile. The Findlay break passes a little west of Van Buren, in Allen township, through North Baltimore, and about two miles west of Bowling Green. Monclova, in Lucas county, is also on this or an altogether similar line. The sags in the rock that are alluded to in the preceding statement become of special interest from facts that will presently be stated. The most important of them are found in the east part of Liberty and in Portage townships, in Wood county. The last named township is almost entirely occupied by one of these depressions. In this discussion it will be noted that the names Waterlime and Lower

Helderberg limestone are used interchangeably. It is an open question as to which designation is to be preferred.

It is along the edge of the Findlay break that the greatest gas wells of the fields have been struck. The Karg well is located, as nearly as possible, at the very summit of the sharpest descent. The Trenton limstone dips westward from the Karg well 100 feet in 1,000 feet of horizontal measure. The Van Buren well holds a similar relation to the break. The Simons well, another of the chief producers, acquires its value by a like relation to the sag that cuts across the territory due north of it, and it is quite possible that a distinct break will be found in this neighborhood.

An important addition can be made to our knowledge of the monocline. It is this: this structural feature can be traced quite distinctly, in the main, by the surface rocks. The western line of junction of the Lower Helderberg and the Niagara limestone, as laid down upon the geological maps of these townships, is in substance the line of the Findlay break. This boundary was established in the original geological survey of Hancock and Wood counties by Professor N. H. Winchell, who explored and reported upon this district. It is surprising to see how close he came to the actual facts, working as he did, not only in a drift-covered, but in an undeveloped region and at a time when much less could be seen of the rocks than now. The lines that he drew stand approved to-day in all essential particulars, and are becoming invested with great economic interest. The wisdom of mapping out minutely these different limestone beds, that underlie the country, was very likely questioned by the farmers who saw the work going forward. It was sure to seem to them a needless and fanciful refinement to call one bed of limestone Waterlime and another Niagara limestone. Both would burn into equally good lime, and this was the main point of value that was recognized in them; but when it is learned that one of these rocks stands for possible oil in the underlying Trenton limestone, and not for gas, and the other for gas in

the same rock and not for oil, there will be none to question the desirability of having the facts upon record. The statements as to the division of the upper Silurian limestones of page 22 of the original Report, and page 33 of the present Reprint, need to be qualified as to this point. The value of the boundary is now seen to be much greater than was there represented, and the disparaging remarks as to the reality of the divisions indicated, must be withdrawn. What was said in that connection, however, as to the impossibility of separating the out-crops of the two series in many parts of northern Ohio, is entirely true.

It now appears that all the gas wells of Ohio that derive their supply from the Trenton limestone are begun in the Niagara limestone, or at least in territory where the Niagara limestone is due. There are possibly cases in which good gas wells have been found, where a few feet of the Waterlime are left lying upon the Niagara; and, on the other hand, the rocks may be deeply eroded, in particular instances, so that the Niagara itself, although originally found in the section, will be wanting or at least reduced to a small measure in the well record, its place in such cases being usurped by invading bowlder clay. But outside of these statements, no further qualification is necessary.

It scarcely needs to be said that the relation of the different limestones to gas and oil production respectively has nothing whatever to do with the limestones themselves; but the vital fact is the relative level at which the Trenton limestone is to be found, and this is indicated to some extent by the different limestones that occupy the surface. The Niagara limestone stands as a matter of course for a higher level of the underlying Trenton than the Waterlime when both strata are found at the same surface elevation above the sea, as they so commonly are in north-western Ohio, and especially in the great gas producing belt of this region. Here, as is shown in the Preliminary Report, the elevations do not vary fifteen feet in as many miles, while the Trenton in the same interval will rise or fall for five or six hundred feet.

It is evident that the driller can with profit extend his geological knowledge. He will also need to enlarge his geological vocabulary. All the upper limestones that he meets, including the Clinton and Niagara, Waterlime or Lower Helderberg, and Upper Helderberg limestones, have thus far been classed together by him as Niagara limestone, unless when some specially hard phase of them has been struck, which then is quite likely to be entered in his record as "gray granite." It is evident, however, that it stands him in hand to recognize the difference between the true Niagara and the overlying Waterlime.

Not only are all the producing gas wells of the new field located upon outcrops of the Niagara limestone, but it is further true that all the oil wells are begun in the Waterlime. To this statement no exception is now known, but exceptions may well occur. It must be borne in mind that this last named formation has a thickness of not less than 500 feet in its full sections. It is only on the edge of the stratum, or moderately close to outcrops of the Niagara, or in other words, near uplifts, that oil is found at all. Elsewhere, the Trenton limestone is carried below the deadlines of the several districts. The prospects of a well can be told in every productive field by the depth at which the casing needs to be set. This fact, too, as is evident, is connected with the level of the Trenton limestone and derives all its significance from this connection. By the length of the casing, which is, as a rule, approximately the same as the thickness of the upper limestone, the depth of the Trenton can be estimated. No well has yet proved productive, in any worthy sense of the word, in which more than 500 feet of casing has been required.

No great wells of the first class have been added to the Findlay field proper. The Karg still stands alone in this important group. The city has drilled, within the last few months, two wells quite near to it. The first of them was about 1,000 feet removed, and while a fairly productive well, when finished, yielding

1,179,000 cubic feet per day, it belongs to an entirely different class from its great neighbor. This city well was the first of the Findlay gas wells to be torpedoed, and its production is said to have been greatly helped thereby. As before stated, it is 1,000 feet from the Karg well, and as it proved, it is 1,000 feet in the wrong direction, because it is further removed from the edge of the steep descent on which the latter stands. The Trenton limestone in it was reached at a higher level above tide by six feet than in the Karg, and all the facts of its production are in harmony with what we should expect from the circumstances now named. The second city well was so located as to fare much better than the first. It comes much nearer the line of the Findlay break; but if it could have been located a few hundred feet further to the westward, it would probably have proved still more vigorous. It is counted one of the strong wells of the Findlay field, after the Karg well.

There has been no opportunity for the last eight months to re-measure the pressure or volume of the wells whose force and flow had been previously determined; but, so far as can be learned, there is little or no abatement of the rock pressure of the field. While the Karg well was blowing into the air, in the later winter and spring of 1886, the rock pressure in all, or at least in most, of the town wells was notably affected, a reduction of twenty-five to thirty pounds being recorded in many of them; but, with the closing of this great outlet, the pressure seems to have returned to the old figures, namely, 390 to 400 pounds per square inch. The best observations have been obtained from the Oil Mill well of McManness & Seymour, which has no connection with any of the pipe lines of the town. In this well, the morning pressure is found steady at the figures named above.

The Kirk well, located on the east bank of Eagle creek, from the testimony of its proprietor, appears to be losing volume and pressure to a considerable extent. It was never vigorous, accord-

ing to the Findlay standard, and its decrease can occasion no surprise. Two other wells, located in the same part of the town, namely, the Pioneer well and the Gas Works well, Nos. 1 and 2 of the Findlay field in order of drilling, are known to have lost a good deal of their original force; but no quantitative statements can be made in regard to them, as they were not satisfactorily measured in their early days, and no opportunity can now be had to gauge them, since they are constantly connected with the main lines of the city supply. The location of these wells, a half mile or more east of the break, will help to explain the fact that they are the first to suffer abatement of flow. By the great series of wells that have been drilled to the west of them, the territory from which they are fed, the common supply has been cut off to some extent; and, furthermore, it is to be borne in mind that these wells were the first to be drilled, and therefore have been drawing longest upon the reservoirs immediately tributary to them. The wells nearest the break, as the Karg, City No. 2, the North Findlay well, and the Cory well, are very happily situated for a long and generous supply. The oil that lies at the foot of the deep descent may be counted as the source of the gas, and along this ascending slope the gas constantly finds its way upward. It would appear to be the wise policy for Findlay, and for the whole western border of the Findlay break as well, to leave the oil untouched in its great reservoirs and to save the entire territory exclusively for gas production. Gas is gold, but oil is lead, at least under the conditions of the market that now prevail. There are no geological conditions elsewhere known in Ohio at all comparable with those that are found along this line of disturbance, so far as gas production is concerned. Any sacrifice of the higher uses of this unique territory to less valuable ones is much to be deprecated.

Three milest east of Findlay the Thorn Tree well is located. It was reported, at the time it was brought in, to have obtained its gas from a depth of ninety-three feet in the Trenton limestone. If

this were a fact, it would be an anomalous one for the entire field; but, according to Mr. C. H. Emerson, under whose direction the drilling was done, gas was obtained all along in the Trenton at the usual horizons, and by no means exclusively or conspicuously at the unusal depth reported. That the well was drilled too deep is obvious from the fact that oil and salt water have been raised in such large volume in connection with the gas as to considerably reduce the value of its production.

(b.) THE VAN BUREN FIELD.

It is hard to say just what territory should be included in the Findlay field. Probably the great wells to the northward will be best treated under distinct divisions.

In Allen township, near Van Buren, the largest gas well of the new field is found. It was drilled by Conroy and Johnson, and is now the property of the North-western Ohio Gas Company. Measured from the casing, six weeks after the flow was struck, the well was discharging 15,000,000 cubic feet of gas every twenty-four hours. In the six weeks in which it was open, no less than 630,000,000 cubic feet escaped into the air. The city of Cincinnati does not use in a year as large a volume of artificial gas as this; but the cost to the city for such a quantity as is here reported at the present rates, which are lower than have ever prevailed before, would be more than three-quarters of a million of dollars.

(c.) THE BLOOMVILLE FIELD.

The most prominent of the divisions of the gas field, in some respects, is a tongue of Niagara limestone that occupies the east side of Henry township and a large part of Bloom township, Wood county, and also includes the southern portion of Perry township. This field begins at North Baltimore and extends to the water tanks six miles west of Fostoria. This district lies in a low arch which is well shown in the accompanying section. The

structure of the rocks from Deshler eastward to Tiffin is represented here. The levels of the well-heads above tide are shown by the figures in the upper line. The depths of the Trenton below tide are indicated in like manner by figures at the bottom of the section. The level of the Trenton limestone at Bloomville is incorrectly given as 310. It should be 360 feet. the drawing is slightly in error as to this point.

The records of two wells located at North Baltimore are instructive in this regard. In well No. 1, the surface of the Trenton limestone was found 451 feet below tide. This well yielded oil in small amount. In the Peters well, on the east side of the town, the Trenton limestone was found seventy feet higher, or 380 feet below tide; and this well is an excellent gas well, though not reaching the figures of great production. From that point eastward for several miles, the Trenton slowly rises. At Bairdstown it is found 314 feet below tide; at the Simons well, 301 feet below; at Bloomdale, 360 feet; and at the Water-Tank wells, 380 to 390 feet below. In the first and last of this series, the lowest levels of the Trenton limestone that are found associated with large gas production in this particular field occur.

The Simons well is the only first-class well in this list. It yielded 12,400,000 cubic feet of gas from the casing the day after it was completed. When brought down to a four inch pipe, its production was doubtless reduced to the amount of two or three million cubic feet per day. This Niagara district, of which we are now treating and which is thus seen to stand for gas producing Trenton limestone, extends from Findlay northward to the south line of Portage township, in Wood county, and from North Baltimore eastward to the Godsend Water Tanks. It forms the largest continuous body of proved gas territory that is now known in the State. In addition to the townships already referred to it, namely, the east side of Findlay township, and parts of Marion, Allen, and Cass townships, Amanda and Washington must also be included

within it, although the gas territory is here developed to only a small extent. Another township will probably be added to the list. A large amount of this territory has been secured by the North-western Ohio Gas Company, a corporation that is displaying great energy and sagacity in its operations in the new field, and that is certain to reap a large reward for its generous investments. The pipes of this company are already delivering gas to Fostoria and Fremont, and will very soon reach Tiffin, Toledo, and other important centers. The wells drilled at Jerry City and the Rocky Ford, in the northern part of Bloom township, and several others that are in the same vicinity were located in one of the sags that have already been described as traversing the field, and the Trenton limestone is not productive in any of them in either gas or oil. Attention has previously been called to these low places in the rock, which are indicated by the presence of the Waterlime in areas where the Niagara is to be expected.

(d.) THE BOWLING GREEN FIELD.

The Bowling Green field has been strengthened to the southward since the date of the last Report, but it has probably reached its limit in this direction in the Portage well. The boundary between the Niagara and the Waterlime occurs at this point, and production to the south of Portage should give oil rather than gas, if anything is found. The most promising territory in the Bowling Green district lies to the westward, so far as geological conditions can be relied upon to guide us. The promise is certainly afforded by the geological structure apparent here, but only the drill can tell whether the promise will be kept. There is room for more than one Karg or Van Buren well in the two miles of the Niagara limestone that extend to the westward of the Findlay break as it passes through Plain township. The descent of the Trenton limestone from Bowling Green in a line due west is 500 feet in seven miles.

The higher levels of the Trenton limestone end quite abruptly a little to the northward of Bowling Green, and the whole series descends from this point toward the lake, a fall of 400 feet being registered between Bowling Green and Toledo, the descent of the surface not being included.

The Findlay break, as has already been stated, continues to the northward, but no satisfactory tests have yet been made of the petroliferous character of the deep rock of this boundary. A well drilled at the sand works west of Sylvania, would find a long section of the upper limestones and would thus require more casing than in the parts of the field at present productive, but it would also find as sharp a descent of all the strata as at Findlay. It seems hardly possible that such a pronounced repetition of the Findlay structure can be entirely without effect in the accumulations that are so eagerly sought at the present time. Of the districts not yet tested, this seems to be one of the most promising, geologically considered. The wells drilled at Perrysburg and South Toledo are hardly to be considered as located upon this line. The main disturbance is evidently two or three miles to the west of them. New conditions would be met in drilling at Sylvania, and the record would become, in any event, a very interesting one. If gas were found in quantity at this point, it could be turned to the best possible account in the manufacture of glass from the Sylvania sandstone, one of the purest and most remarkable sand deposits of the country. Gas has been developed within the year, for the first time, at a few other points in north-western Ohio; and at other localities, new wells have been added to those already successful to a greater or less degree. The facts pertaining to this field can be briefly stated.

(e.) THE CAREY WELLS.

Carey has added three new wells, drilled at the public expense, to the three already reported. They are all practical failures, and

the town has no results at all adequate or satisfactory, to show for the money spent in exploration. All these wells are located on the Waterlime. The Niagara rises abruptly to the west of the town. There is good geological reason in this fact to expect more favorable results in that direction; and there is a still better ground for confidence in the experience of the two fairly productive wells that have been struck in this region, one at Vanlue and the other in Ridge township, Wyandot county. It is therefore probable that this enterprising town will yet reach its much desired supply of light and power without being obliged to depend on long and costly pipe lines.

(f.) THE OAK HARBOR WELLS.

Oak Harbor, Ottawa county, has continued the work of drilling deep wells, the first of which was reported in the previous edition. The wells are located on a narrow belt of Niagara limestone that forms one of the two prolongations into which the great mass of this formation in Hancock, Sandusky and Seneca counties divides as it approaches the lake shore, as pointed out by Winchell in 1870. A syncline or depression, occupied by the Waterlime, interrupts the continuity of the Niagara for a few miles in Ottawa county. The Trenton limestone is struck in the Oak Harbor wells at 720 feet below tide, a depth for which the great fields have no use whatever, but which, under the compulsion of pronounced and favorable structure, gives some value to this outlying territory. Of the four wells drilled at Oak Harbor, the last is said to be the best. An effort was made to obtain a measure of its flow when first brought in, but the force of the current was not strong enough to render the Robinson method available, and an anemometer was not at hand. The volume probably does not exceed 200,000 cubic feet per day, and may be much less. The conditions here are similar to what would be found at Sylvania, though in some respects less favorable than there. The supply of Oak Harbor, whatever it proves to be, will probably be derived

from territory lying to the east rather than to the west of the town.

(g.) THE FREMONT WELLS.

Fremont has continued to drill deep and shallow wells, until the number reaches or exceeds twenty, and in so doing, it has added some interesting and important facts to the history of the new field in northern Ohio. It was noticed by good observers, that quite a flow of gas was found in all the early wells a little above the top of the Medina shale, and further, that there seemed to be but little addition to the supply derived from going 800 feet deeper into the Trenton limestone. If new gas was found in the latter formation, it was thought to be counter-balanced by the loss of that from the upper horizon through the operation of drilling. These observations, which were made by Mr. George O. Harlan, presently led to a practical test by him of the points involved. He secured a portable drilling machine, and put down, without previous experience, a well on his own premises to the Medina shale. The gas flow was small, but still it was amply large enough for household use. Mr. Harlan then began the work of drilling other wells of the same character; and during 1886 he completed a half dozen or more of them, all of which admirably answered the purpose for which they were drilled, namely, furnishing light and heat for household supply. The cost of such wells complete, was about $700. The source of the gas for these shallow wells is the Clinton limestone and not the Medina shale as was stated in the first edition. It will be remembered that the Clinton is represented in the preliminary Report as an oil rock at many points, (page 31) when found in out-crop, so that it is not surprising to find it when under cover charged with petroleum or its derivatives. The highest measured production of this group of wells is 17,000 feet per day, but a volume of this amount yields an abundant supply for a half dozen houses, if they are conveniently located with reference to this purpose.

The deep wells of Fremont are, with possibly one or two exceptions, too light producers to serve a valuable purpose for general supply; but all of those drilled so far have yielded, with one exception, dry gas. The history of the tenth deep well, drilled in the center of the town, is very instructive. In it, the Trenton limestone was reached at a higher level by fifty feet, than in any of the other wells by which it is surrounded on all sides. The results that were to be expected from this advantage of structure were fully realized. The well probably produced more gas than all the other wells of the town combined. The supply would probably have reached 200,000, or perhaps even 300,000 cubic feet per day, if the well had been kept in its best condition. The advantage was, however, lost by drilling fifty feet into the limestone and reaching oil and salt water, from which the gas could with difficulty, if at all, be separated. A deep well has recently been drilled at the residence of President Hayes for household supply, and it is said to be one of the most successful of the series.

Fremont has added, as shown above, a new gas horizon to our column, namely the Clinton limestone. At least the supply is more regular and equable from the Clinton rock at this point than elsewhere; and Fremont has also supplied a striking illustration of the dominant effect of structure on gas and oil accummulation. The North-western Ohio Gas Company is now supplying Fremont from its great wells in Hancock and Wood counties.

(h.) THE MERCER COUNTY WELLS.

Mercer county is coming into prominence as a source of gas. The wells drilled at Celina were as dry as any in the field. Those drilled at Union City and Greenville, to the south-ward, were also reported to be free almost from the traces of gas or oil, but undismayed by these failures, Hon. Dennis Dwyer, of Dayton, Ohio, drilled a well in October last, on the edge of the Cranberry Marsh,

near St. Henry's, in Granville township. The location of the well was determined by the fact that a north-east line from Findlay and Lima would traverse the Cranberry Marsh. When the Trenton limestone was reached, a small volume of gas was obtained, but the well was presently "shot" and a great flow of gas resulted. Its blaze, illuminating the sky at night, could be seen for a dozen or more miles on every side. The well was presently brought under control, and the gas, when measured in February, 1887, as delivered through a two-inch pipe, was found to be 2,650,000 cubic feet per day. If measured through the casing when the well was first torpedoed, it would doubtless have shown more than three million cubic feet. It is an invaluable discovery for the western counties. The closed pressure of the well is said to be 375 pounds to the square inch. A second well, drilled a half mile distant from the first, was much less vigorous in its flow, but it still delivered an amount of gas that would be no insignificant addition to a pipe line. A third well, recently drilled by other parties, four and a half miles south-west of St. Mary's and two miles south of the east end of the reservoir, in Auglaize county but near the border of Mercer, is reported as a vigorous producer. All are located in the Niagara limestone. The importance of this opening gas field, located where it is, cannot well be over-estimated. The great oil pools of Lima, Cridersville and St. Mary's, cannot fail to have gas reservoirs somewhere around them, even if not very near at hand. These oil wells are all begun in the Water-lime; and the gas horizon should here, as elsewhere, be sought in the nearest outliers of the Niagara limestone.

To the southward, drilling has been done in all the counties of western Ohio; but the results thus far, so far as gas production is concerned, oscillate between insignificance and zero. Gas for domestic use can doubtless be obtained at a few points, perhaps at many, but no manufacturing supplies have yet come to light. Some of the attempts have been very bold and persistent. Day-

ton has sunk the drill to a deeper level geologically, than has ever before been reached in Ohio, the bottom of the well being 1,500 feet below the surface of the Trenton limestone.

In summing up the chief developments of the year in the production of gas from the Trenton limestone, the following points come distinctly into view:

1. The large supplies of gas are limited to comparatively small areas. Nine townships of Hancock county, six of Wood county, one of Wyandot, one of Auglaize and one of Mercer, in whole or in part, constitute both the actual and the fairly probable gas territory up to the present time. The total area of these several districts will approximate 325 square miles. Of this total area, only a small portion has been proved to any such extent as to really warrant the name of gas territory being applied to it. The most that can be said for much of it is that it is possible gas territory. Good or fair wells have been struck in three townships of Wood county, in six of Hancock, and in one each of Wyandot, Auglaize and Mercer. These centers of production are, however, certain to be increased. The most prominent undeveloped territory of this kind is to be looked for in Auglaize, Mercer, and possibly in Hardin. The presumptive territory of the principal counties named, namely, Wood and Hancock, is only partially tested yet.

2. All of these gas wells, without exception, are located in the Niagara limestone, so far as surface rock is concerned, evidently not from any influence of this wide-spread sheet on gas production in itself considered, but merely because it stands for a higher level of the real gas rock, which is the underlying Trenton limestone. All the gas wells begin in the Niagara limestone; but it would not answer at all to infer that the converse statement is true, namely, that all wells which are begun in the Niagara limestone will prove to be gas wells. Not one mile in ten

in Niagara territory promises even fairly well in this regard, so far as the tests made to the present time go.

3. The geological explanation of the gas territory of Hancock and Wood counties, and of its oil production also, is clear, beyond misunderstanding or misinterpretation. The gas and oil accumulations are accounted for and conditioned by a tongue of high-lying Trenton limestone, that follows the Findlay break as far north as Bowling Green. The structure in question comes very clearly to view in the map which shows the topography of the Trenton limestone (page 126). This tongue of Trenton limestone is a trap for gas and oil, which rise into it from all sides and find no way of escape until the drill reaches and releases them. The largest and most promising production is found in this particular region, because there is here a large tributary territory, or in other words, because the trap is large. Given an equal rainfall and similar conditions of surface for two rivers, the one which drains the larger area must be the larger river. Given two ridges of gas and oil producing rocks, other things being equal, the larger must yield the most abundant supply. Every ridge or arch of the Trenton limestone is a trap. The Findlay arch differs from the rest simply in being a thousand times larger than others that traverse the rocks.

4. The gas lies above but generally not far removed from oil accumulations. On the margins of all the great oil pools, gas is to be expected, and in fact, it cannot fail, but whether east or west, or north or south of the oil accumulations, depends entirely on the structural facts in the locality which we may chance to be examining. To insist upon one direction only for a gas supply as connected with the oil, or to count on one direction as sure to be preferred above another in this connection, is absurd.

PRODUCTION OF GAS WELLS.

Convenience will be served by the classification of the leading gas wells according to their production. The strong wells can be referred to a few divisions, the boundaries of which will be easy to hold in memory. Any such classification, of course, is purely arbitrary, and its only claim to acceptance must rest upon the purpose that it serves. There are very few wells in the field, the daily production of which exceeds ten million cubic feet. These will be counted wells of the first order. There are probably a half dozen others, mostly of the newer wells, that exceed five million cubic feet without reaching ten million feet of daily production. Wells of this grade, at least, are positively reported, and the claim is apparently based on measurements. All such may be counted as wells of the second order. The third order will take in those wells whose daily flow ranges from one to five million cubic feet. Wells producing from five hundred thousand to one million cubic feet per day, may in like manner be styled wells of the fourth class; and finally, the wells of the fifth class will embrace all those ranging from a hundred to five hundred thousand cubic feet per day. This can be expressed in tabular form:

CLASSIFICATION OF GAS WELLS.

	Cubic ft.		*Cubic ft.*
First order, daily production exceeds..	10,000,000		
Second order, daily production between	5,000,000	and	10,000,000
Third order, daily production between.	1,000,000	and	5,000,000
Fourth order, daily production between	500,000	and	1,000,000
Fifth order, daily production between..	100,000	and	500,000

All wells below this lower limit would be classed as small wells and but doubtfully adapted, at best, to any purpose except domestic use.

WELLS OF THE FIRST CLASS.

There are but three wells known in this group. The author is responsible for some conflicting statements in regard to these wells, and correction will here be made. The errors have resulted from measuring the wells under different conditions, one, for example, from the casing, and another from a four inch or smaller pipe. The full effect of this reduction of the opening to the well was not at first appreciated. The great wells named in the order of their production are as follows: first, the Van Buren well; second, the Karg well; third, the Simons well. The first of these wells was fortunately measured both from the casing and from a four inch pipe immediately after the well was packed. All of the measurements were made by the Robinson method, which, in fact, is the only scientific method that has been made public.

The Van Buren well showed an open pressure in the casing of six pounds, indicating a velocity of the current of 1,105 feet per second, and a daily yield of 14,984,352 cubic feet, or, in round numbers, 15,000,000 cubic feet. In the four inch pipe, the open pressure rose to twenty and a half pounds, indicating a velocity of 1,677 feet per second, and a daily yield of 12,614,400 cubic feet. The loss of the well by the reduction from a five and five-eighths inch opening to a four inch opening is seen to have been 2,370,000 cubic feet per day, a result that will, perhaps, occasion surprise, but the great practical importance of which cannot escape observation.

The Karg well was never measured from the casing, but only from the four inch pipe. A statement to the contrary that appears in the Preliminary Report was inadvertently made. The open pressure in this well was fifteen pounds, and the daily volume of gas production, 12,080,000 cubic feet. Through the casing, its production would certainly have reached, or very nearly reached, 14,000,000 cubic feet per day.

The Simons well was measured from the casing when first completed and was found to be discharging 12,421,968 cubic feet per day. The steam gauge in the current indicated an open pressure of forty-three pounds. When reduced to a four inch pipe, the volume must have shrunk to 10,000,000 cubic feet per day, or thereabouts. Put in tabulated form, the facts are as follows:

	Pressure in the Casing.	Pressure in 4 in. Pipe.	Yield from Casing.	Yield from 4 in. Pipe.
Van Buren well..	6 lbs.	20½ lbs.	15,000,000	12,614,400
Karg well........	-	15 "	———	12,080,000
Simons well......	4 lbs.	—	12,422,000	———

The wells of the remaining groups will not be treated of at this time further than to say that the Heck well, the Barnd well, probably the Columbia Gas Works well, and possibly two or three others of the northern wells, seem to belong to the second order; and that the Bairdstown well, the Bloomdale wells, together with the Cory, Briggs, Jones and City wells No. 1 and 2 of Findlay, and several others, and the St. Henry's well No. 1, belong to the third order. It is in this group that all of the larger Indiana wells, definite figures from the production of which have been published, appear to belong. The Robinson tables need to be somewhat extended. For a clear statement of this system in its application to the measurement of wells, the reader is referred to page 108. But when the tables were made the supposition was that the Karg well stood for high water mark of the gas production of the new field, and that the figures which would serve for this would certainly answer for all the rest. This supposition, however, has proved erroneous, and the fifteen pounds of open pressure of the Karg well were replaced by twenty and a half pounds of open pressure in the same sized pipe in the Van Buren well. Furthermore, when the system was applied to the great Pennsylvania wells, a pressure of forty-five pounds was found, or three times that of the Karg well. This latter figure was obtained

from the Andrews well of the Raccoon district, of Beaver county, Pennsylvania. The table, as extended to any limits that can possibly be required, is given below:

$\frac{P'}{P''}$	M.
1.035	.1000
1.071	.1414
1.107	.1732
1.145	.2000
1.183	.2236
1.222	.2444
1.263	.2646
1.304	.2828
1.346	.3000
1.389	.3162
1.433	.3317
1.478	.3464
1.525	.3606
1.572	.3742
1.620	.3873
1.669	.4000
1.719	.4132
1.770	.4243
1.822	.4354
1.876	.4472
1.930	.4585
1.986	.4690
2.043	.4796
2.101	.4899
2.160	.5000
2.472	.5477
2.816	.5916
3.193	.6325

$\frac{P'}{P''}$	M.
3.606	.6708
4.054	.7071
5.062	.7746
7.607	.8944
10.960	1.0000

It is also to be remarked that the specific gravity of the Findlay gas is probably counted a little too high in the Robinson tables. It is there taken as .6; but the calculations of density based upon chemical analysis give .57 instead. A correction for this change in specific gravity would show an increase in yield of all the wells by a small percentage. But it seems scarcely necessary to disturb on this account the figures that have already obtained so wide a currency. The proper correction for the change indicated is .026. About 100,000 cubic feet per day would be added by this correction to the flow of the Van Buren and the Karg wells.

In the Preliminary Report, it is inadvertently stated that the volume of the gas as shown by the Robinson method of measurement is the volume at 60° Fahrenheit. This is erroneous. The volume obtained is that of the gas at the temperature with which it issues from the well. This is generally between 32° and 38° Fahrenheit. A correction will need to be made if the volume at 60° is required.

2.—THE OIL PRODUCTION OF THE NEW FIELD.

A few statements must now be made as to the present facts and the future prospects of the oil production from the Trenton limestone in Ohio. A year ago, not a well in the field exceeded 150 barrels per day, and it may be even questioned whether any well

had fairly reached this limit. During the last few weeks, however, one well is reported to have produced ten times this amount, or 1,500 barrels in a day, while a number have reached the thousand barrel limit, some of them maintaining a rate of several hundred barrels for week after week. Single wells have produced as much as 20,000 barrels of oil without the aid of a pump, maintaining a rate of much over 100 barrels per day at the end of three or four months' service. The Cory well, near Findlay, is probably the greatest producer yet struck in the field. Within the last few weeks it has brought to the surface more than 10,000 barrels of oil. It probably deserves to be ranked as the largest oil well yet drilled into the Trenton limestone. The production of the entire territory has been variously estimated. It is certain to have exceeded 10,000 barrels per day for the whole field during the early months of 1887. The March production of the Lima field will be found on a subsequent page. But whatever the facts of present production may be, there is no ground for doubt that the field could easily be made to yield twenty or thirty thousand barrels in a few weeks' time under the encouragement of a higher price for oil than has hitherto ruled. All of the production thus far has been held in check or even repressed by the low price to be obtained when the oil is brought to the surface. The developments here referred to are simply astounding. It is hard to believe what we see and know. There have been many surprises for both geologist and driller in the history of petroleum production thus far, but there certainly has never been one before approximating to that which is derived from the history of the North-western Ohio Oil and Gas Field. It is hard for either geologist or driller to adjust himself to the facts of every day experience; and the larger the knowledge possessed of the geological series involved, the greater apparently is the difficulty in realizing the present and the prospective production.

The contribution to economic geology made by the new field

is one of first class importance and world-wide interest and significance. The discovery of Findlay gas and Lima oil has added immensely to our knowledge of the possibility of stored power in the crust of the earth. Hitherto the Carboniferous and Devonian formations have marked the lower limit of stored power on the large scale, the one containing coal and the other having been found in the latter half of the present century, to hold vast stocks of gas and oil; but the new horizon drops at one step to the bottom of the Lower Silurian age, a half mile or more below, in stratigraphical order, the lowermost great source of power hitherto known to men. For a large part of the country there is no possibility of further surprises of this sort in the descending column, from the fact that the Trenton limestone in it lies very near the granite, and between the two but a single sandstone intervenes. If, as certain theories vainly urge, petroleum were of chemical origin, there would be no improbability of its being obtained even from the granite, but among all the claims for its wide extension, none have gone as far as this.

(a.) THE LIMA OIL FIELD.

The Lima field is much the most important source of Trenton limestone oil. Lima itself, where the main development of a year ago was going forward, has become already forgotten. The city wells have run down in production; and very few among them, perhaps not a single one, has fairly paid for itself; but to the southward and westward, a great oil field is opening out that is destined to take rank with the largest yet discovered in the American continent.

The chief development thus far has been in Bath, Ottawa, Perry and Shawnee townships of Allen county, and in Duchouquet township of Auglaize county. Its limits are, however, as yet unknown. The last three townships constitute the great centers of production at present. All the conditions pointed out in the Pre-

liminary Report pertaining to the levels of the limestone source have been maintained in the subsequent development of the field. The Trenton shows itself wonderfully sensitive to variations of elevation in connection with its yield of gas and oil. Every foot of elevation appears to count.

The geology of this field does not come out to view with anything like the distinctness of the Findlay field thus far. In fact, it can hardly be said that the key to its structure has yet been found.

The main points in its geology that are now recognized are the following: The Lima oil field constitutes a very flat lying tract of the Trenton limestone. It is as nearly a level terrace as an area of this sort ever becomes. The very gentle slope that exists in it is mainly to the northward. It does not amount to more than four feet to a mile in any case through the productive territory, and is often reduced to one or two. In east and west lines, there is often neither rise nor fall for several miles. The limestone floor is slightly undulating, it is true; but an average depth can easily be made out where drilling has gone forward as extensively as here. The rises in the floor, or in other words, the knobs and bosses of the great limestone sheet are always favorable to production, other things being equal, such as the grain of the limestone, for example. A slight elevation of the limestone floor of a well above other wells that surround it will give to it an entirely different character from that of its neighbors. The Garvey gas well, so-called, located on the Jacobs land, adjacent to the Shade property, just south of Lima, furnished a case in point. The well was reported as a producer of dry gas, the first and only one in the field at the time. It maintained this character for ten days or two weeks, and great value would have attached to it, if it had continued it; but presently it began to spray oil, and later to flow oil, like the neighboring wells. The level was run to this well, and the Trenton limestone was found to have been reached six or eight feet higher than in any one of the dozen wells that form a cordon

around it. The Trenton in the Shade well was about 390 feet below tide, but in the gas well it was 384 feet below tide. These six feet of advantage made it a gas well for two weeks. No example can be more instructive with regard to the points under discussion.

As to the possibilities of the Lima field in oil production, all who are acquainted with such interests recognize them as very great. The whole history of the field has been one of repression and discouragement of production thus far. The opening price of forty cents per barrel for the oil was counted on all sides as a temporary price only; and it was confidently expected that as soon as tankage and transportation were found, an advance would be made. The price first offered has proved temporary, it is true, but instead of moving upwards, as producers had counted upon its doing, it has receded, first to thirty-five and finally to thirty cents per barrel. The latter mark was reached on the first day of February, 1887. It is obvious that wells must be very good ones to endure the last named figures. All moderate pumping wells will be excluded from the list of possible production under these conditions.

As to the qualities of the Lima oil, it is to be regretted that final statements cannot now be made. The judgment expressed in the Preliminary Report in regard to its character is undoubtedly too favorable. It is impossible at the present time to obtain an unprejudiced judgment upon the subject. All agree that the sulphuretted compounds that render the oil so offensive are pretty closely interwoven with its very substance and are thus hard to dislodge and destroy; but all further agree that the last result can be obtained with a sufficient outlay of labor, time and money. When the oil has been apparently thoroughly deodorized, it has often been found that the offense would return. It is certainly, however, within the power of science to effect a complete and permanent expulsion. The main question is, at what expense can this be done? This question cannot now be answered. An estimate of ten

cents per barrel is made by some refiners, but others believe a larger outlay necessary for effective work. As to the percentage of illuminating oil also, the testimony accumulated is to some extent conflicting. The figure most commonly given in this connection is fifty per cent. Of one thing we are sure: There seems to be no question whatever as to the excellent character of the refined product of Lima oil when it has passed through all the needful processes of correction and purification.

By some it is claimed that the lubricating oil is of a very superior character, and others report it as unable to endure a satisfactory cold test, so that it is not adapted for winter use. The first statement is probably true in regard to it.

As to the important question, what is Lima oil worth when Pennsylvania oil is quoted at sixty-five cents? for example, no well supported answer can now be given. The oil market can scarcely be said to be an open market. It is not at all certain that it is governed or gauged by the actual facts of production and consumption. Vested interests, accumulated stocks, the systems of storage and transportation, the interest of refined oil as against crude oil,—all these constitute factors whose inter-working and effects the public are entirely unable to follow.

Lima oil constitutes a fuel of great value, and its use, if present rates are maintained, seems certain to be widely extended; and it cannot be doubted but it is unquestionably the cheapest fuel, so far as absolute power is concerned, within the reach of any of our communities. Several patent processes for burning it are in successful operation. On this side, there would even seem to be a possible relief in the way of better prices, but here again the unknown elements forbid any positive conclusions.

At all events, the new field has made a wonderful addition to the stocks of power which the State was heretofore known to hold. This stored power is certain to become increasingly valu-

able as the world grows older. It seems almost unfortunate that these particular accumulations should be unlocked so soon. From some points of view, the low prices that now prevail, discouraging as they do, extravagant production, are no real or permanent disadvantage to the field. The wasteful American system of development and exploitation will make the quickest possible work with any form of mineral wealth in any case. Three refineries are already in operation, one of them of very large proportions, and three systems of tankage and distribution by pipe lines are now established in the field.

Beyond the Lima field proper, comes the St. Mary's field. A number of wells have been drilled in and about St. Mary's, the first of which attained but moderate success; the second and third were failures, and the fourth is of rather uncertain value; but in the last, four miles south-west of the town and two miles south of the east end of the reservoir, gas is reported to have been secured in large and profitable volume, within the last few days. The flow is estimated at more than two million feet per day and the rock pressure is said to be 400 pounds to the inch. The St. Mary's field, in any case, is scarcely separated from the general tract which we have been already describing.

An authoritative newspaper statement supplies the following facts as to the present condition of the field:

" During the month of March, there were twenty producing oil wells drilled in this field, with a production ranging from a two hundred and fifty barrel flowing well to a thirty barrel pumping well. The new production, added to the previous report by the wells drilled in March, is 1,600 barrels. The production on the last day of last month was 8,760 barrels of oil a day. The March production, added to this, makes a daily production of 10,360 barrels for the Lima oil field. There are now a total of 424 producing oil wells in this field. The oil runs made by the Standard Company this month were 279,492.98 barrels, against 198,119.85

barrels last month. The two independent companies have completed their pipe lines and 35,000-barrel tanks, but have run only a small amount of oil, but will be ready for active business in a week or ten days, when business in the oil field will be more brisk. There are fourteen wells drilling at present, and about thirty rigs up and building."

(b.) THE FINDLAY OIL FIELD.

The character of the Findlay oil field has been continually improving under the slow but steady development that has gone forward during the last year. It reaches out west of the town and a little to the south for a distance of five or six miles, with a breadth of about half of its length. Its boundaries, however, cannot yet be defined on all sides. To the eastward the line is sharply enough marked by the Findlay break. All the oil comes from the lower side of the monocline, and all the oil wells are begun in the Waterlime formation. The best of the producing levels seem to be where the Trenton limestone is found from 460 to 490 feet below tide. The levels of the later wells have not been obtained, but so long as the series continued to be followed, all the facts were entirely conformable to the deductions from the earliest wells. There are between sixty and seventy wells in the Findlay pool, and the daily production is not much less than 4,000 barrels. The oil field, thus far, has had no chance. There is a small refinery located here, the work of which is claimed to be entirely successful.

(c.) THE NORTH BALTIMORE OIL FIELD.

A well drilled just west of the Findlay break, on the eastern side of Henry township, Wood county, and three miles north of North Baltimore, during the last winter proved a remarkably successful one. It is credited with the largest production that had up to that time been recorded in the field, namely, 1,500 barrels of

oil in a single day. This astonishing production caused great excitement through the new oil centers. Territory was eagerly taken up on all sides, and a number of wells have since been drilled in this immediate vicinity, several of which have shown great vigor. There are ten producing at the present time. They are said, however, to run down rapidly from their large initial flow and the field does not seem to possess as solid and substantial a character on this account as Lima and Findlay proper. It is, however, apparent that before such a judgment is fully warranted, further exploration must be made. Structure is so vital an element in production, and even its minor phases become so influential, that it may yet remain to find a better balance between oil and gas than in the wells already finished. The North Baltimore field is rated at about 500 barrels at the present time.

The Lima field, with the extensions already claimed for it, the Findlay and the North Baltimore fields constitute the present oil centers of north-western Ohio. The production of the entire field is apparently in excess of 14,000 barrels per day, but, under present conditions, it is impossible to make any definite statements.

3.—THE GENERALIZATIONS OF THE PRELIMINARY REPORT.

In the first edition of the Preliminary Report, a few conclusions were drawn from the facts then in hand as to the most important geological features involved in the new field. They were as follows:

1. The great gas wells of the Findlay and the Bowling Green fields obtain their supplies from territory in which the Trenton limestone is between 300 and 400 feet below tide.

2. The oil production of the Findlay field is limited to those

portions of the country in which the Trenton limestone is not more than 500 feet below tide.

3. The oil production of the Lima field is limited to territory in which the surface of the Trenton limestone is not more than 400 feet below tide.

4. The districts of north-western Ohio, and especially those adjoining the Findlay field, in which the surface of the Trenton limestone lies more than 500 feet below tide, will not prove productive in oil or gas. In other words, there are dead-lines extending through the different portions of the field, and of these the line of 500 feet below tide is by far the most important.

The tentative character of these conclusions was fully recognized from the fact that they were based on a comparatively small number of examples. The experience of the last year renders it necessary to modify these conclusions to a small extent; but, so far as now appears, the facts on which the conclusions were based were fortunately representative facts, and no better general statements could be made, even at the present time with the vastly greater number of examples, than were made one year ago. So far as the Lima field is concerned, not a single exception is known in which valuable production has come from below the 400 feet dead-line. In the Findlay oil field it is probable that one or more of the later wells have passed the 500 feet line, although no clear case of this sort is known; but no figure could be named to-day which would make any improvement on that which was before given. The most sagacious of the operators engaged in the development of the field have come to the same conclusion, as a result of their own experience and observation. They judge the promise of a well long before the Trenton limestone is struck, and in fact, from the depth at which the casing stands. The casing, as is understood, must extend to the bottom of the upper limestones to shut off the salt water which they carry. The facts in this connection are as follows: In the Findlay field the general height of

the surface is a very little short of 800 feet above tide. The thickness of the shales that lie between the upper limestone and the Trenton oil rock has just about the same measure, namely, 800 feet. The depth below tide, therefore, at which it will be found, will be approximately equal to the thickness of the upper limestone combined with the thickness of the drift, or, in other words, the depth at which the casing stands. The statement already made amounts to the same thing as to say that no well is found productive in which it is necessary to use more than 500 feet of casing. Minor exceptions may be found to this claim; but the exceptions cover only a few feet at the most, and are very few in number.

The first condition stands unimpugned by all the experience of the field, so far as known. The second, as has just been shown, is as close to the facts as any general statement that could be made. The third is unbroken, so far as known, by a single exception that deserves the name. All the interest, therefore, pertaining to these conclusions centers in the fourth. Is it true, in view of the large and costly experience that has been gained during the last year in western Ohio, that the productive character of the Trenton limestone ceases when its surface goes more than 500 feet below the tide level? The map included in this supplement answers this question in a striking way and renders the true significance of this 500 feet line apparent, so far, at least, as the Hancock and Wood county oil and gas belt is concerned (see page 126). This 500 foot line marks the boundary of the narrow tongue or prolongation of the Trenton limestone, from which more or less steep descents occur on every side. All the rocks within this boundary have a decided advantage on this account.

In the original statement of this conclusion, it now appears that account enough was scarcely made of the minor folds or local ridges that traverse the Trenton in all portions of its extent. Such inequalities are found in the best of the oil and gas producing ter-

ritory, and there is every reason to expect them elsewhere in equal amount. Wherever the drill in its descent should chance to strike upon one of these elevated portions or on the edge of some break in the series, a measure of production would be sure to be attained, other conditions being favorable. This has happened in a number of conspicuous instances; and when such wells are first struck, the reports of their production seem to set aside altogether the deductions in question, but careful observation has shown in every case, or in almost every case thus far, that the rule, after all, deserves to stand. The most notable exceptions are Carey, Fremont, Oak Harbor, and Tiffin, which were named in the first edition, and to these Bryan and Lancaster may be added. In regard to the first three towns, no further statements are necessary, as their present status has been briefly given on a preceding page. Both Carey and Fremont have spent their money without anything like a fair equivalent in the fuel and light that they have obtained. Fremont is now piping gas from the great fields to the south of it, and Carey will doubtless soon follow its example. Oak Harbor appears to better advantage than any other towns in this list. It is quite possible that its wells are returning a full equivalent for the investment, and that this locality thus makes an exception to the 500 foot line. Tiffin is now preparing to use gas from the great wells of the North-western Ohio Gas Company in Hardin and Wood counties, but exploration is still going forward in the immediate vicinity of the town. Quite discordant structure was revealed in the case of the two wells first drilled, and as such structure is specially favorable in many cases to gas or oil production, it is quite possible that supplies of some value may yet be found here, if the exploration is sufficiently continued. It will be a pleasure to record the success of so persistent and expensive a search as Tiffin has made; but it seems scarcely probable that a large field can exist here in connection with the facts as to the disposition of the oil rock in this and adjacent territory, so far as the lines of level are concerned.

Though both oil and gas have been found at Tiffin, the quantity and promise are not thus far such as to lead to its being counted an exception to the deduction as to the 500 foot dead line.

BRYAN.

Bryan, the county seat of Williams county, in the extreme north-western corner of the State, after a long and tedious descent, reached the Trenton limestone during the last winter, but the rock was scarcely penetrated when the tools became fast in the well, and it thus became necessary to drill around the first set of tools. This was successfully accomplished on the 16th of February, 1887. At a depth of thirty-two feet in the Trenton limestone, a vigorous flow of gas and oil was released. Up to this time, all of the attempts to secure oil or gas in the north-western counties had been marked by a monotonous line of failures and a favorable result was therefore not expected by the people of Bryan. The first flow of the well was very demonstrative. It is scarcely to be wondered at, under all the circumstances, that it caused the greatest excitement in the community, and, from the reports that went out, in all the centers of the new production. The published accounts were greatly exaggerated, as was natural, under the circumstances, but the facts themselves were certainly important and imposing. As nearly as can be learned, on the first day on which the oil and gas horizon was reached, the well produced 100 barrels of oil, together with several hundred thousand cubic feet, perhaps a half million cubic feet of gas; but both oil and gas began to abate at once. The oil flow on the 18th was judged to be scarcely in excess of fifty barrels per day. By the 19th, it was reduced to thirty barrels, or less. By the 20th it had fallen to ten barrels; and by the 27th, the well ceased delivering oil altogether, while the gas fell off during the same time to a considerable extent. The well was more than 2,000 feet deep. There were more than 1,000 feet of solid limestone. The casing required to be set as low as 1,300

feet. The outlay to date will not fall below $5,000. The Trenton was found at 1,240 feet below tide. At Wauseon, twenty miles east, the surface of the same stratum had fallen to 1367 feet below tide. This shows that Wauseon lies in a deep furrow of the Trenton, and that the limestone at Bryan, deep though it is, has a decided relative advantage in respect to its level. If future work is done here, it will probably appear that the limestone where first struck constitutes a ridge, or that the point in question belongs to the edge of a terrace of the Trenton limestone. Structure is found to dominate wherever opportunity occurs for a study of the facts, and it is therefore entirely safe to conclude, after the experience already recorded, that it dominates everywhere, and that if work enough is done in any field of any notable production, a clear explanation of the field will come to light. It was found impossible to obtain a measure of the gas flow of the Bryan well when it was last visited on account of the oil that was delivered with the gas. Up to the present writing, Bryan is not thought to make a note-worthy exception to the deduction which we are now considering.

LANCASTER.

The experience of Lancaster remains to be briefly described. Lancaster is located in Berea grit territory. This stratum was found at a depth of 400 feet below the surface and twenty feet in thickness. The Ohio shale series is thinner here than in most parts of the State in which it occurs, measuring about 630 feet. The Devonian limestone was struck at a depth of 1,050 feet, and according to the driller's samples, there were nearly 1,000 feet of these upper limestones. The descent through them was long and tedious, the casing finally standing at 1,500 feet, but even then not shutting off salt water altogether. A small vein seems to enter in the lower series of the well. The Clinton group is expanded here, as has been stated on a previous page, to 200 feet or more; and it contains a considerable proportion of red rock, in which are a

number of feet of its perfectly characteristic iron ore. Gas was found in a calcareous bed of the Clinton at a depth of a little less than 2,000 feet. The composition of the gas-rock is as follows:

Carbonate of lime	80.60
Carbonate of magnesia	4.57
Silicious matter	8.65
Iron and aluminum	3.50

To one acquainted with the composition of our limestones in their outcrops, these figures will be found very significant. We have but one limestone in this portion of our scale that has a composition like this, namely, the Clinton of south-western Ohio. The figures here given would answer well for a typical specimen of the Clinton, with the single exception that the silicious matter is in too large proportion. From the casing, the yield of gas, according to an anemometer measurement obtained February 9, 1887, is 74,880 cubic feet per day. The flow is said to be fully maintained to the present time, and the drill is still slowly descending to the Trenton horizon. Crestline is the first and only town in Ohio that is located in Berea grit territory which has thus far succeeded in reaching this wished-for goal, the Trenton limestone, for which it set out. It obtained nothing whatever for its outlay except the experience and geological knowledge that were derived from the progress of the work. Lancaster now bids fair to be the second town in Ohio to hew its way down from the Berea grit territory to the Trenton limestone. The depth of the Crestline well is said to be 2,850 feet. The Lancaster well will probably exceed this extreme measure. Lancaster would prove a bold exception to the deduction under consideration if a valuable flow of gas should be found in the Trenton limestone. As to the present supply, it is hard to say whether or not it should be counted an exception to another conclusion, to this effect, namely, that every locality holds but a single productive horizon of high-pressure gas. It could scarcely

become profitable to secure such small supplies as the Lancaster well now produces at so great depth and under so great disadvantages. Other wells are to be drilled in Lancaster forthwith, and the question will soon be decisively settled as to the value of this and other horizons here.

LINES AND BELTS IN THE NEW FIELD.

It becomes increasingly evident to all who can free themselves from preconceived theories in studying the development of the new oil and gas region, that the only lines that are influential here are the structural lines of the Trenton limestone. It is mainly the relative elevation of this stratum at any one point as compared with its elevation in other adjacent territory that determines its value as an oil or gas rock. From the Indiana line in Darke and Mercer counties a broad tract bears north-eastward as far as Findlay. As has been shown already, it is on this north-east tract, which has been named the Lima Axis, that the oil production of Allen and Auglaize counties is found, as well as the gas production of Auglaize and Mercer counties. Within this tract minor factors of elevation or disturbance will give to one or another well great advantages over its fellows, just as in a productive corn-field accidental circumstances will give to certain hills the advantage over those that make the bulk of the field, but to connect by a line two rank corn-hills, in different portions of the field, and to expect greater fertility in the parts of the field traversed by this line than elsewhere, would be recognized by everyone as absurd. It is scarcely less absurd, the moment a strong well is brought in at any point on this broad and flat uplift, to connect it by a line on the map with some other well of vigorous production elsewhere and to expect unusual value in the territory underneath the line. There is a north-east line in the field, as already indicated, but there is another line much more marked that is not north-east. The Findlay break is essentially a north and south line with a trifling deflection to the north-west.

As to whether the interval between the Findlay and Lima fields will yet prove good territory, it is too early to determine. The general levels of the Trenton in this interval are within the limits of production elsewhere, and certainly there is nothing discernible that points to foreordained failure here.

The north and south line from Findlay to Bowling Green is depressed in a part of this interval to such an extent as to prevent the territory being considered available for gas. Oil may well enough be looked for on the east side of Liberty township, Wood county, and on the west side or perhaps throughout the whole of Portage township, in the sags occupied by the Lower Helderberg formation.

IS THE TRENTON LIMESTONE AVAILABLE AS A GAS AND OIL ROCK IN EASTERN OHIO?

The discovery of Findlay gas, accompanied as it is by the remarkable movement at present in progress in that town in real estate and in all kinds of business interests, brings to every community the questions, What chance have we to obtain like supplies? Does the Trenton limestone underlie this region? If so, at what depth and under what conditions? Is it worth while to drill to it? The answers to these important questions have already been given, or at least have been involved in the discussions of the preceding pages; but to avoid all possible grounds of confusion and uncertainty in regard to them, a few plain statements will be further made at this point:

1. The Trenton limestone, which is the Findlay gas rock, is supposed to underlie all of eastern Ohio. It is believed to be a universal sheet throughout this entire region.

2. The depth at which it will be found depends, of course, upon the location of the town from which the question comes. The rocks of eastern Ohio dip prevailingly to the south-east and to the south with a normal rate, in the first instance, that is seldom

less than twenty feet to the mile. In addition to this normal descent, there is a great thickening of the higher formations in this region, which amounts to the same thing as an unusually steep dip of the underlying rocks. The facts can be best seen in a few separate sections. Take a line from Findlay, through Bucyrus, Crestline and Mansfield to Massillon. The Findlay section has been given already and need not be repeated here.

At Bucyrus, in the well drilled last summer, the drift and the basal beds of the Ohio shale were together 130 feet thick; the upper limestones were found 816 feet thick; and the great shale series 1,170 feet thick, making the Trenton limestone 2,145 feet below the surface and 1,235 feet below tide water.

At Crestline, a few miles to the eastward, the depth at which it was claimed the Trenton limestone was found is 2,850 feet. This would make its upper surface about 1,650 feet below tide. The upper limestones here are given at 857 feet in thickness. Crestline is the most eastward point at which the Trenton limestone has yet been struck in Ohio.

At Mansfield the section is as follows:

Waverly group	555 feet.
Bedford and Ohio shales	645 feet.
Devonian limestone struck at	1,200 feet.

And drilled into until a depth of 2,000 feet was reached.

The Trenton limestone here must be more than 1,000 feet below the present bottom of the well. The progress of the well was arrested by an influx of salt water from its regular horizon in the Devonian and Upper Silurian limestones.

At Massillon, still further east, the section was as follows:

Drift	45 feet.
Conglomerate	40 feet.
Waverly Group	470 feet.
Bedford and Ohio shale	1,860 feet.
The Devonian limestone was struck at	2,515 feet.

It is almost idle to speculate upon the depth at which the Trenton limestone would be found at Massillon. It would not be less than 4,000 feet.

At Findlay, the lower portion only of the great series of upper limestones is found. At Bucyrus the entire series is found, but the top of it is only 130 feet below the surface. The same horizon, namely, the summit of the Upper Helderberg limestone, is reached at Crestline at 800 to 900 feet below the surface; at Mansfield, at 1,200 feet below the surface; and at Massillon, at 2,515 feet below the surface.

When it is remembered that this limestone series invariably contains salt water and generally contains it near the bottom of the series, and when it is further borne in mind that the casing off of the salt water is an indispensable necessity for gas wells, the difficulty in the way of drilling to the Trenton limestone in this eastern territory becomes evident. Mansfield, Mt. Vernon and Newark are all cases in point. Each has struck salt water at or about 2,000 feet below the surface.

3. After these statements, it is scarcely necessary to answer specifically the third question. Is it worth while to drill to the Trenton limestone? The first answer is that suggested by the facts that have just been stated. To drill to the Trenton limestone in eastern Ohio is impracticable. It would be an immensely expensive task. While the resources of the driller are certainly adequate, if money enough is forthcoming to the drilling of a single well, a multiplication of such wells is obviously out of the question, unless great value is reasonably sure to be found at the bottom.

But in the second place, there is not the slightest reason to expect any returns from the Trenton limestone commensurate with the outlay, if it should be reached by the drill. No large enough folds have been found or indicated, outside of the Findlay field, to make an adequate foundation for large production. The line of

500 feet below the sea marks the lower boundary of the last and only large elevated area of the Trenton limestone.

On these accounts it is deemed safe to say that the western boundary of the shales, or of Division No. 2 on the map that accompanies the Preliminary Report, marks also the eastern limit within which the Trenton limestone can be wisely sought. All of Ohio east of this line must build its hopes for oil and gas on other horizons than the Trenton limestone.

That the difficulty of going down to the Trenton in these districts is very great is seen from the recent experience of the towns already named, Mansfield, Mt. Vernon and Newark. Each of them has undertaken the descent with ample means and with a determination to overcome all difficulties; but two of them have already been stopped by the influx of salt water at about 2,000 feet below the surface, a depth so great that, while not impossible, it is impracticable to case it out. The third town of this list has found the salt water, but is still struggling to overcome it.

To all inquiries, therefore, as to whether it is worth while to attempt to drill to the Trenton limestone in eastern Ohio, the answer is an emphatic *no*. There is nothing in geology and nothing in the results of practical experience to give the slightest encouragement to undertake this long descent.

SECTION IV. THE TRENTON LIMESTONE IN NORTH-EASTERN INDIANA AS A SOURCE OF GAS AND OIL.

A few statements derived from the experience of north-eastern Indiana during the last year will here be introduced. The State Geologists of Indiana seem to have clearly seen that the relations of the Cincinnati uplift to the geological history of their State are not satisfactorily accounted for by the current statements in regard to this great feature of the geology of the eastern portion of the Mississippi valley. Their views can be seen in brief discussions of questions connected with this factor. Prof. E. T. Cox touches upon the subject in his report of 1878 (page 14), and Mr. Maurice Thompson alludes to it in his report of 1885–6 (pages 14 and 15). Both appear to have found it impossible to reconcile the facts that they met with the old idea of an arch advancing from Cincinnati north-easterly to the islands of Lake Erie, as the dominating feature of this portion of the country. They are certainly right in demurring to this claim; but no clear substitute for it could be presented until the drill should have given us opportunities never enjoyed before to learn the real features of the Trenton limestone and to determine its connection with the present disposition or arrangement of the rocks of the State.

In Mr. Thompson's report of 1885–6, to which reference has already been made, there is an interesting discussion by Prof. S. S. Gorby of certain structural disturbances which he finds in north-eastern Indiana, and to which he gives the name of the Wabash arch. The general line of disturbances, as he states it, bears from the north-west to the south-east across the State. The facts of broken structure upon which he bases the existence of an arch occur at many points in the Wabash valley. The fact that the bedded rocks are uncovered in this great valley more frequently

than elsewhere in consequence of the removal of the drift deposits which has been effected by the river in its post-glacial history would seem to explain the multiplication of instances of disturbed rocks that occur here. If there were more exposures of the strata in north-eastern Indiana there would certainly be more disturbances of this character to be noted. All the phenomena that he records can be duplicated throughout several thousand square miles of north-western Ohio. The lower limestone floor of north-western Ohio and north-eastern Indiana is found to lie in an uneasy and much disturbed condition; the disturbances, however, not always being referable to any large or great movements. The title which Prof. Gorby has introduced may prove to some extent misleading, as it would naturally be interpreted as indicating an arch extending in the westerly direction of the Wabash valley, and the author certainly does not hold to such a view. The Wabash arch in its larger features, if a disturbance extending to the north-westward, would seem to be part and parcel of the Cincinnati uplift.

Dr. A. J. Phinney, of Muncie, Indiana, an assistant on the State Geological Survey, has also contributed much interesting and important information upon the wells that are being drilled, both in the report of 1885–6 and in timely newspaper articles of more recent date. The facts as to the wells of the State that are here made use of are mainly borrowed from the articles published by Dr. Phinney in the various ways already indicated.

Western Ohio and eastern Indiana are obviously made out of one piece, geologically considered, and they have shared a common history, so far as the structural features of their strata are concerned. The series of the two States are identical, beginning in the Ohio valley and advancing to the northern lakes. The common column is as follows, the strata being named in descending order:

Ohio shale, basal portion, surface rock in north-western Ohio and north-eastern Indiana.

Devonian limestone, surface rock in north-western Ohio and north-eastern Indiana.

Lower Helderberg, or Waterlime, surface rock in north-western Ohio and north-eastern Indiana.

Niagara limestone, surface rock in western and northern Ohio and eastern Indiana.

Clinton limestone, surface rock in southern Ohio and southern Indiana.

Medina shale, perhaps wanting in Indiana.

Hudson river group, surface rock in south-western Ohio and south-eastern Indiana.

Utica shale, Trenton limestone, } Mainly under cover in both States.

The surprising discovery of gas and oil in western Ohio in 1885–6 could not fail to awaken interest and to provoke the trial of the drill in the adjoining State, the more so because of the obvious fact that the south-western direction of the early developments from Findlay to Lima pointed directly to the possible, or perhaps even probable, extension of productive territory beyond the Ohio line. This north-east or south-west line has since been found to be an important structural feature of the districts concerned, but by no means the only important structural feature in the new field. The main structural lines of the Cincinnati uplift, as indicated by the highest levels of the Trenton limestone, have already been shown to extend north-westerly from Butler and Preble counties, Ohio, into Indiana. Within the last named State these high levels of the Trenton can be followed by the records of the drill through Wayne, Randolph, Delaware, Blackford, Grant, and Miami counties, although in regard to the last, the statement is based altogether upon the facts of its surface geology. The Trenton maintains an elevation above tide as far as Eaton, Delaware county. A line joining Eaton, Indiana, and Eaton, Ohio, marks a high level of the Trenton limestone throughout its entire

extent. The Trenton limestone drops slowly from this elevated tract in all directions, the most conspicuous facts now in hand indicating its fall to the southward and also to the north-eastward. In this high tract of the Trenton, the Lima axis of Ohio takes its rise, falling very slowly to the north-eastward and advancing through north-western Ohio in a broad and low fold that has already been amply described and that is represented in the map that accompanies this supplementary report.

It seems, at the present writing, that the situation of the Trenton limestone in Indiana, where favorable to gas production, follows the line of facts already pointed out in north-western Ohio, namely, that *gas is found in the Trenton limestone mainly when the Niagara limestone makes the surface rock.* On the western and southern border of the Upper Silurian outcrop, where the entire upper limestone series is much reduced in thickness, it appears that the Trenton is found relatively high enough to serve as a gas rock when the Waterlime, or possibly even when the Devonian limestone makes the surface. The well records at hand show a considerable reduction of the Hudson river series throughout the entire State of Indiana as compared with similar sections in Ohio. This reduction was recognized and reported in the descriptions already given of Ohio wells. The series was found to be progressively shortening as it was followed toward the Indiana border. The Medina shale is not distinctly shown in Indiana, either in outcrop or under cover. It is probably lost by overlap of the Clinton limestone.

The northern boundary of this Niagara area enters Indiana from Van Wert county, Ohio, passes through the northern portion of Adams and Wells counties, through the westerly portion of Huntington, and thence follows the Wabash valley as far as Peru, Miami county. Here it turns abruptly to the southward, passing through the center of Howard county, and bearing a little eastward through Tipton, Hamilton, Madison and Henry counties. The re-

gion here referred to is indicated on the accompanying map. There is a tongue of Niagara limestone also that stretches southward from this area by Newcastle to Madison and along the Ohio valley, which is not considered in this description, as no important facts are at hand in regard to it. There is also another Niagara area represented on the geological map of Indiana in the north-western corner of the State, including Lake, Portage, La Porte, Newton, and Jasper counties, in whole or in part. No sections have been secured from this tract, and no inference is fairly warranted as to the conditions of the underlying Trenton limestone here; but some of the facts displayed in the geological map of the State seem to promise favorable conditions for gas and oil, as suggested by Mr. Thompson in his report of 1885–6. It may render the boundary of the Niagara limestone already given still more distinct if the towns located on or near it are named in this connection. The leading towns upon this boundary are as follows: Decatur, Bluffton, Huntington, Wabash, Peru, Kokomo, Tipton, Anderson, Pendleton, and Newcastle. The counties included *within* the boundary already given, are as follows: Jay, Blackford, Grant, Delaware, and Randolph. The Trenton limestone underlying this main area of the Niagara limestone in Indiana occupies a high level, as has been shown by the drill, in Randolph, Delaware, Blackford and Grant counties; but its descent to the westward is very slow as shown in its level at Kokomo, where it is only eighty-six feet below tide. At Tipton, to the south-eastward from Kokomo, its elevation is given as 129 feet below tide. At Anderson it appears to be about twenty feet above sea level, but from Anderson to Indianapolis, the descent is quite steep, the Trenton lying more than 800 feet below tide at the last named place. The western boundary by Tipton and Kokomo suggests the Bowling Green and Findlay break in its general trend and relations. If it should prove to be a line of break or sudden descent, there would be great promise in it. It is to be borne in mind that the gas supply of Kokomo is quite as vigorous,

according to published accounts, as of any Indiana town. Within this large area of the Niagara, it seems scarcely worth while, judging from the experience of Ohio, to look for definite and persistent arches or anticlinals. The conformation of the surface of the Trenton with all its minor flexuosities and irregularities will be sure to influence its relations to oil and gas, and these minor features may prove the chief explanation of the good fortune of one town and the failure of another. The principal lines of structure in this part of Indiana, it must be repeated, are not south-westerly lines advancing across the State from the Findlay and Lima field, but north-westerly lines parallel to the western boundary of the Upper Silurian region.

Kokomo, Noblesville, Marion, Anderson, Portland, Muncie, Hartford City, Alexandria and several other towns have reported more or less vigorous gas wells: The northern border of the Niagara seems to be descending at a rate which would soon carry it below the limit of productive territory elsewhere. At Bluffton the Trenton is 215 feet below tide; at Decatur, 460 feet below; and at Fort Wayne, 643 feet below. The extreme north-eastern corner of Indiana is below the Ohio dead-line, at least for oil and gas from the Trenton limestone. Oil accumulations are to be looked for around the margin of the gas fields of Indiana. No facts have yet come to light as to any large production here, but it seems hardly probable that the drill will fail to reach some notable oil pools, if its work is still continued. The natural location for these pools would be upon the outer margin of the Niagara limestone, beyond but not far beyond the gas-producing territory. As in Ohio, the Waterlime in Indiana is likely to be the surface rock where oil production is found. Within the main Niagara area the conditions for large oil production would seem less favorable.

The gas and oil of Indiana, so far as they are derived from the Trenton limestone, are seen in the light of the few statements

now made to be in the closest accord with the same valued products in north-western Ohio, and the two States must be studied together, so far as these phases of their geology are concerned, if either is to be clearly and fully understood.

SECTION V.—THE BEREA GRIT AND THE OHIO SHALE AS SOURCES OF GAS.

Little needs to be added to the statements of the Preliminary Report in regard to the Ohio shale. On the map accompanying this volume, a broad band bordering Lake Erie and stretching southward to the Ohio river is seen to be represented as a territory of low-pressure gas, derived from the Ohio shale. It is also marked by the figure 2 upon the map. This band embraces all the out-crops of the Ohio shales and in addition, about as much more territory as they furnish, taken from the margin of the Waverly group. The aim is to follow the Waverly group inward and downward until the Berea grit has fallen to 300 or 400 feet below cover in the valleys. No great value can be expected from this stratum where it is under less cover than this. In fact, all the gas found in such territory will hold the character of shale gas, as is seen in the wells drilled at Berea. This map only puts into graphic form the statement of the Preliminary Report as to the gas of the great shale formation.

On the map of the gas production of the State as at present developed, which accompanies this volume, thirty-six counties, in whole or in part, are included in the territory of high-pressure gas from the Berea grit. This great area makes quite an imposing appearance on the map, and would seem to show unlimited possibilities for this section of the State in the way of natural gas supplies. The promise of the map as thus indicated, is, however, far better than the promise of the territory itself as developed by

the drill. The map implies that in this area the Berea grit is found under deep enough cover to become a reservoir of high-pressure gas. It is not to be doubted that the great shale series that underlies it is always ready to do its part in furnishing oil and gas to the reservoir nor that the Cuyahoga shale above is always ready to serve as roof or cover for the gas reservoir. These two facts are co-extensive with the field. But the character of the Berea grit itself is somewhat uncertain and makes one of the factors that are always in question. The stratum may be too fine grained or too impure to serve a good purpose as a reservoir, or there may not be enough of it. This is the first element of uncertainty in the oil and gas production of eastern Ohio. A second and a far graver source of uncertainty exists, namely, in the lack of the right structure or arrangement of the rocks. Here lies, without doubt, the weakness of eastern Ohio as a source of high-pressure gas or large stocks of oil. It must be confessed that the results of drilling during the last year are quite discouraging as to the resources of this wide-spread and elsewhere valuable sheet, the Berea grit. Of the thirty-six counties named above, thirty of them have in one or more localities made a test of the character of the Berea grit as it is found beneath them during the last year. A number of them have repeated their trials again and again and in different localities, and some have continued to drill to great depths in the strata; but in not a single instance, outside of the Macksburg field and Washington county, have the wells that were drilled proved successful. Aside from the territory already excepted, not a well is reported that would come into the fifth order of gas wells, those, namely, that produce gas in excess of 100,000 cubic feet per day, or that has yielded in the whole of its history more than 100 or 200 barrels of oil.

This monotonous record of failure is undeniably discouraging. It is granted that the area actually tested forms but a small percentage of eastern Ohio. It is granted that one well or a dozen wells occupy but a small part of a county; but the fact that not a

solitary success has been thus far registered during the last year, is the depressing feature of the case.

A little encouragement can perhaps be borrowed from the fact that none of the wells drilled, or at least not more than one or two, have been located with any reference to the structural features of the district in which they are located. Some of these features are recognizable in the territory under consideration. If they are studied with care enough, the hope is that locations can be made which will afford to the driller all the advantage there is in the situation of the underlying rock. This work is just beginning, and though no successes are chronicled in it to date, it would seem that the main encouragement to further exploration in the eastern half of Ohio must be derived from the aid that can be obtained from investigations of this character. It can scarcely be true that there is but one Macksburg in the State or that the gas production of the Neff wells must continue to hold the highest place.

SECTION VI.—TABLE OF ELEVATIONS.

The levels of the Trenton limestone have been shown to be such vital facts in gas and oil production in these new fields that it is deemed best to give the surface elevation of a number of points in western Ohio and northern Indiana, so that the facts as to the gas and oil rock, wherever drilling happens to be going forward, can be readily determined. The elevations given below are derived in the main from railroad levels, and are to be considered the levels of the iron upon the track in front of the station of the railway to which the figures refer as authority, unless otherwise stated. It must be acknowledged that the figures given here have not been reduced by any close or careful comparison to an

absolute standard, but they are the best that are attainable at the present time. The Ohio figures have been compiled from various sources but the convenient arrangement in which they now appear is due to the present report of the Secretary of State, which contains by far the most valuable collection of data on this point that has yet been published.

The figures for Indiana are taken directly from the Dictionary of Altitudes of the United States Geological Survey.

TABLE GIVING ELEVATIONS ABOVE SEA LEVEL IN THE WESTERN COUNTIES OF OHIO.

(Lake Erie above Sea Level 573 feet.)

ALLEN COUNTY.

STATION.	AUTHORITY.	ELEVATION.
Beaver Dam	Lake Erie & Western R. R	863.
Bluffton	" " "	834.
Cairo	Dayton & Michigan R. R	814.
Delphos	Pitts., Ft. W. & Chicago R. R	786.
Elida	" "	798.
Harrods	Chicago & Atlantic R. R	1012.
Lafayette	Pitts., Ft. W. & Chicago R. R	936.
Lima	Dayton & Michigan R. R	875.
"	Chicago & Atlantic R R	903.
Spencerville, L'k 15	Miami & Erie Canal	847.
Summit bet. Westmin'r and Harrods	Chicago & Atlantic R. R	1032.
Westminster	" "	997.

AUGLAIZE COUNTY.

Cridersville	Dayton & Michigan R. R	889.
New Bremen	Lake Erie & Western R. R	1038.
St. Mary's, Lock 13	Miami & Erie Canal	864.25
Wapakoneta	Dayton & Michigan R. R	891.

BROWN COUNTY.

Aberdeen, Main and Cross streets	Whittlesey	545.
Georgetown	Cin'ti, Georgetown & Ports. R.R.	942.
Hamersville, water tank	" " " "	976.
White Oak Viaduct.	" " " "	871.
County line between Brown and Clermont counties	" " " "	937.

BUTLER COUNTY.

Carlisle	Cin'ti, Ham. & Dayton R. R.	696.
College Corner	" Indianapolis R. R.	990.
Gano	C., C., C. & I. R. R.	661.
Hamilton	Cinti, Ham. & Dayton R. R.	597.
Henderson	C., C., C. &. I. R. R	656.
Jones Station	Cinti, Ham. & Dayton R.R.	672.
Kyle's	C., C., C. & I. R. R.	718.
Maud's	" "	759.
Middletown	" "	667.
Oxford	Cin'ti, Ham. & Indianapolis R.R.	918.
West Chester	C., C., C. & I. R. R.	745.

CHAMPAIGN COUNTY.

Catawba	C., C., C. & I. R. R.	1065.
Kennard	N. Y., P. & O. R. R.	1174.
Kingston	" "	1097.
Mechanicsburg	C., C., C. & I. R. R.	1088.
North Lewisburg	N. Y., P. & O. R. R.	1082.
Urbana	" "	1031.

CLARKE COUNTY.

Bowlusville	N, Y., P. & O. R. R.	966.
Enon	P., C. & St. L. R. R.	1024.
Moorefield	C., C., C. & I. R. R.	1021.
Selma	P., C. & St. L. R. R.	1083.
South Charleston	" "	1126.
Springfield	N. Y., P. & O. R. R.	908.
" Union Depot	P., C. & St. L. R. R.	991.

CLERMONT COUNTY.

STATION.	AUTHORITY.	ELEVATION.
Aurelia	Cinti, Georgetown & Ports. R. R.	886.
Bethel Station	" " " "	905.
Branch Hill	P., C. & St. L. R. R.	590.
Centerville	Cin'ti, Georgetown & Ports. R. R.	870.
Glen Este	Cin'ti, Georgetown & Ports. R. R.	876.
Kyle's	" " " "	860.
Miamiville	P., C. & St. L. R. R.	580.
Milford	" "	552.
Mt. Carmel	Cin'ti, Georgetown & Ports. R. R.	897.
New Richm'd Branch at crossing	Cincinnati & Eastern R. R.	834.
Olive Branch	Cin'ti, Georgetown & Ports. R. R.	832.

CLINTON COUNTY.

Anderson's Fork	Col. & Cincinnati Midland R. R.	1055.
Blanchester	Cin'ti., Wash. & Balti. R. R.	977.
Clarksville	Cin'ti & Musk. Valley R. R.	833.
Clinton Valley	Col. & Cincinnati Midland R. R.	1000.
Cuba	" " " "	1047.
Martinsville	Cint'i, Wash. & Balti. R. R.	1043.
Melvin	Col. & Cincinnati Midland R. R.	1070.
Reeseville	Cin'ti, & Musk. Valley R. R.	086.
Sabina	" " "	1066.
Todd's Fork	Col. & Cincinnati Midland R. R.	1042.
Vienna	Cin'ti, Wash. & Balti. R. R.	1130.
Wilmington	Cin'ti, & Musk. Valley R. R.	1017.

CRAWFORD COUNTY.

Broken Sword Cr'k	Pitts., Ft. W. & Chicago R. R.	916.
Bucyrus	" " " " "	930.
Crestline	" " " " "	1162.
" summit near	C., C., C. & I. R. R.	1177.
Galion	N. Y., P. & O. R. R.	1169.
Leesville	Pitts., Ft. W. & Chicago R. R.	1135.
Robinson	" " " " "	1073.

DARKE COUNTY.

STATION.	AUTHORITY.	ELEVATION.
Ansonia	C., C., C. & I. R. R.	1006.
Arcanum	I., B. & W. R. R	1054.
Dawn	C., C., C. & I. R. R.	1018.
Greenville	P., C. & St. L. R. R.	1055.
Union City	C., C., C. & I. R. R.	1105.
Versailles	" " " "	977.

DEFIANCE COUNTY.

Defiance	Wabash, St. L. & Pacific R. R.	698.
" Maumee river.	" " " "	648.
"	Miami and Erie Canal	667.
Hicksville	B. & O. R. R	762.
Mark Center	" " "	731.
Prairie Run	Dayton & Michigan R. R.	700.
Standley	" " "	731.
White's Mill	" " "	717.

DELAWARE COUNTY.

Ashley	C., C., C. & I. R. R.	985.
Condit	Cleve'd, Akron & Col. R. R.	1086.
Delaware	C., C., C. & I. R. R.	903.
"	Col., H. V. & Toledo R. R.	927.
Eden	C., C., C. & I. R. R.	975.
Galena	Cleve'd, Akron & Col. R. R.	923.
Hyatt's	Col., H. V. & Toledo R. R.	933.
Lewis Center	C., C., C. & I. R. R.	960.
Powell	Col., H. V. & Toledo R. R.	918.
Radnor	" " " "	953.
Summit	" " " "	972.
Sunbury	Cleve'd, Akron & Col. R. R.	970.

ERIE COUNTY.

Ceylon	L. S. & M. S. R. R	609.
Huron	" " "	598.
Kelley's Island	U. S. Lake Survey	614.
Sandusky	L. S. & M. S. R. R.	593.
Venice	" " "	585.
Vermillion	" " "	596.

FAYETTE COUNTY.

STATION.	AUTHORITY.	ELEVATION.
Bloomingburg	Col. & Cincinnati Midland R. R.	988.
Washington C. H.	Cin. & Musk. Val. R. R.	983.
White Oak	" " " "	925.

FRANKLIN COUNTY.

Alton	P., C. & St. L. R. R.	928.
Columbus, U. Depot	Col., H. V. & Toledo R. R.	747.
N. E. cor. State House	Jennings	781.
Signal Office	U. S. Signal Office	805.
Edwards Station	Col., H. V. & Toledo R. R.	755.
Elmwood	" " " "	844.
Grove City	Col. & Cincinnati Midland R. R.	960.
Groveport	Col., H. V. & Toledo R. R.	738.
Lockbourne	Scioto Valley	720.
Morgan's	Col. & Cincinnati Midland R. R.	835.
Olentangy	Col., H. V. & Toledo R. R.	822.
Westerville	Cleve'd, Akron & Col. R R.	875.
Winchester	Col., H. V. & Toledo R. R.	769.
Worthington	C., C., C. & I. R. R.	913.

FULTON COUNTY.

Archbald	L. S. & M. S. R. R.	730.
Delta	" " "	819.
Pettisville	" " "	753.
Swanton	" " "	684.
Wauseon	" " "	768.
" Summit	" " "	780.

GREENE COUNTY.

Beaver	P., C. & St. L. R. R	808.
Cedarville	" " "	1035.
Claysville	" " "	756.
Goe's	" " "	863.
Harbine's	" " "	806.
Jamestown	Dayton & Ironton R. R.	1071.
Kneisley	C., C., C. & I. R. R.	802.
Oldtown	P., C. & St. L. R. R.	828.

GREENE COUNTY—Concluded.

STATION.	AUTHORITY.	ELEVATION.
Osborn	C., C., C. & I. R. R	830.
Spring Valley	P., C. & St. L. R. R	758.
Xenia	" " "	928.
Yellow Springs	" " "	978.

HAMILTON COUNTY.

Batavia Junction	P., C. & St. L. R. R	491.
Camp Dennison	" " "	570.
Carthage	C., C., C. & I. R. R	551.
Cedar Point	Cin'ti, Georgetown & Ports. R. R	726.
Chester Park	C., C., C. & I. R. R	508.
Cincinnati	Low water city datum	440.
" Signal Sta	U. S. Signal office	620.
Cleves	Cin'ti, Ind., St. L. & Chi. R. R	497.
Columbia	Cin'ti, Georgetown & Ports. R. R	503.
Delhi	Cin'ti, Ind., St. L. & Chi. R, R	502.
Forestville	Cin'ti, Georgetown & Ports. R. R	834.
Glendale	Cin'ti, Hamilton & Dayton R. R	640.
Linwood	P., C. & St. L. R. R	503.
Mt Washington	Cin'ti, Georgetown & Ports. R. R	766.
Newton	P., C. & St. L. R. R	494.
North Bend	Cin'ti, Ind., St. L. & Chi. R. R	497.
Norwood	Cin'ti Northern R. R	626.
Plainville	P., C. & St. L. R. R	492.
Pleasant Ridge	Cin'ti Northern R. R	658.
Red Bank	P., C. & St. L. R. R	501.
Sharon	C., C., C. & I. R. R	601.
Silverton	Cin'ti Northern R. R	825.
Terrace Park	P., C. & St. L. R. R	555.
Valley Junction	Cin'ti, Ind., St. L. & Chi. R. R	499.

HANCOCK COUNTY.

Arcadia	Lake Erie & Western R. R	806.
Arlington	Toledo & Southern R. R	862.
Findlay	Lake Erie & Western R. R	782.
Godsend water t'ks	B. & O. R. R	750.
Rawson	Lake Erie & Western R. R	821.
Stuartsville	Toledo & Southern R. R	815.
Van Buren	" " "	782.

HARDIN COUNTY.

STATION.	AUTHORITY.	ELEVATION.
Ada	Pitts., Ft. W. & Chicago R. R.	956.
Blanchard's Fork	" " " "	900.
Dunkirk	" " " "	949.
Forest	" " " "	938.
Hog Creek Marsh	" " " "	947.
Kenton	I. B. & W. R. R	1015.
Mt Victory	C. C. C. & I. R. R	1036.
Preston	Chicago & Atlantic R. R	1007.
Ridgeway	C. C. C. & I. R. R	1059.
Scioto river, bed of	I. B. & W. R. R	953.
SilverCreek summit	" " "	1118.

HENRY COUNTY.

Alma	Dayton & Michigan R. R	710.
Deshler	B. & O. R. R	721.
Hamler	" " "	723.
Holgate	" " "	722.
Liberty Center	Wabash St. L. & Pacific R. R	683.
Napoleon	" " " "	680.
Sand Hall	" " " "	739.
Texas, lock 12	Miami & Erie canal	661.4

HIGHLAND COUNTY.

Bald Mountain	Orton	1250.
Fisher's Knob	Orton	1300.
Fort Hill	Locke	1232.
Greenfield	Cin'ti. Wash. & Balti. R. R	893.
Hillsboro	" " " "	1075.
Leesburg	" " " "	893.
Lynchburg	" " " "	1001.
Paint Creek	" " " "	896.
Samantha	Orton	1124.
Sinking Spring	Whittlesey	723.

HURON COUNTY.

STATION.	AUTHORITY.	ELEVATION.
Bellevue	L. S. & M. S. R. R	755.
Centerton	B. & O. R. R	873.
Chicago Junction	" " "	901.
Greenwich	C. C. C. & I. R. R	1037.
Havana	B. & O. R. R	813.
Monroeville	L. S. & M. S. R. R	725.
New Haven	B. & O. R. R	918.
New London	C. C. C. & I. R. R	980.
Norwalk	L. S. & M. S. R. R	719.
Pontiac	B. & O. R. R	763.
Wakeman	L. S. & M. S. R. R	862.

LOGAN COUNTY.

Bellefontaine	I. B. & W. R. R	1216.
" summit near	C. C. C. & I. R. R	1346.
Bellefontaine summit 1½ miles east of	Ohio Geological Survey—Hill	1540.
DeGraff	C. C. C. & I. R. R	989.
Gretna	" "	1086.
Harper	" "	1299.
Quincy	" "	1050.
Rushsylvania	" "	1236.
West Liberty	I. B. & W. R. R	1099.

LUCAS COUNTY.

Air Line Junction	L. S. & M. S. R. R	607.
Holland	" " "	641.
South Toledo	Wabash St. L. & Pacific R. R	639.
Swanton	L. S. & M. S. R. R	685.
Sylvania	" " "	652.
Toledo, Union d'p't	" " "	580.
Toledo, low water in Maumee river	Wheeling & Lake Erie R. R	573.
White House	Wabash St. L. & Pacific R. R	653.

MADISON COUNTY.

STATION.	AUTHORITY.	ELEVATION.
Duff's Forks	Col. & Cin. Midland R. R.	895.
London	P. C. & St. L. R. R.	1049.
Mount Sterling	Col. & Cin. Midland R. R.	915.
West Jefferson	P. C. & St. L. R. R.	908.

MARION COUNTY.

Acton Summit	C. H. V. & T. R. R.	943.
Berwick	N. Y. P. & O. R. R.	918.
Clifton's	Chicago & Atlantic R. R.	982.
GreenCamp, water t'k	N. Y. P. & O. R. R.	920.
Marion	C. C. C. & I. R. R.	979.
Morral	C. H. V. & T. R. R.	908.
Owen's	" " "	957.
Prospect	" " "	918.
Summit	" " "	983.

MERCER COUNTY.

St. John's	Geological Survey—Winchell	1003.
" " hills south	Geological Survey—Winchell	1064.
St. Mary's, canal level	Whittlesey	851.

MIAMI COUNTY.

Kessler	I. B. & W. R. R.	925.
Laura	" " "	970.
Ludlow Falls	" " "	900.
Miami City	P. C. & St. L. R. R.	744.
Piqua	Dayton & Michigan R. R.	918.
Tippecanoe City	" " "	843.
Troy	" " "	850.

MONTGOMERY COUNTY.

Alexandersville	C. C. C. & I. R. R.	725.
Brookville	P. C. & St. L. R. R.	1033.
Dayton, D. & M. Cr.	Miami Canal	739.
"	Union Depot	743.
Harshmanville	C. C. C. & I. R. R.	783.
Miamisburg	" "	714.
"	Cin'ti, Hamilton & Dayton R. R.	749.
Stillwater Junction	P. C. & St. L. R. R.	791.

OTTAWA COUNTY.

STATION.	AUTHORITY.	ELEVATION.
Danbury, Geodetic S.	U. S. Lake Survey	594.
Elmore	L. S. & M. S. R. R	658.
Genoa	" " "	629.
Graytown	" " "	601.
Martin	" " "	606.
Oak Harbor	" " "	596.
Port Clinton	" " "	581.

PAULDING COUNTY.

Antwerp	Wabash, St. L. & Pacific R. R	729.
Cecil	" " "	723.
Indiana State line	" " "	745.

PREBLE COUNTY.

Eaton, sill of old C H.	Whittlesey	1044.
El Dorado	P. C. & St. L. R. R	1178.
Florence	Cin'ti, Richmond & Chicago R. R.	1140.
New Paris	P. C. & St. L. R. R	1020.
Sonora	" " "	1039.

PUTNAM COUNTY.

Belmore	Dayton & Michigan R R	732.
Columbus Grove	" " "	752.
Leipsic	" " "	746.
Ottawa	" " "	713.

SANDUSKY COUNTY.

Clyde	L. S. & M. S. R. R	691.
Fremont	" " "	632.
Lindsey	" " "	622.

SENECA COUNTY.

Alvada, summit	Col. H. V. & Toledo R. R	851.
Attica	B. & O. R. R	964.
Bascom	" "	783.
Fostoria	Lake Erie & Western R. R	782.
Kansas	" " "	731.
Republic	B. & O. R. R	885.
Tiffin	" " "	759.

SHELBY COUNTY.

STATION.	AUTHORITY.	ELEVATION.
Anna	Dayton & Michigan R. R.	1018.
Botkins	" " "	954.
Houston	C. C. C. & I. R. R.	959.
Pemberton	" "	1063.
Russia	" "	971.
Sidney	" "	969.
"	Dayton & Michigan R. R.	1001.
"	Miami & Erie Canal	949.
Spafford	C. C. C & I. R. R.	1033.
Summit	Dayton & Michigan R. R.	1053.

UNION COUNTY.

Broadway	N. Y. P. & O. R. R.	1032.
Dover	C. C. C. & I. R. R.	971.
Irwin	" "	1012.
Marysville	" "	999.
Milford Center	" "	996.
Richwood	N. Y. P. & O. R. R.	948.

VAN WERT COUNTY.

Conway	Pitts. Ft. W. & Chicago R. R.	791.
Delphos	" " " "	784.
Enterprise	Chicago & Atlantic R. R.	847.
Dixon	Pitts. Ft. W. & Chicago R. R.	798.
Middlepoint	" " " "	784.
Rivare	Chicago & Atlantic R. R.	851.
Van Wert	Pitts. Ft. W. & Chicago R. R.	784.

WARREN COUNTY.

Corwin	P. C. & St. L. R. R.	729.
Fort Ancient	" " "	669.
Franklin	C. C. C. & I. R. R.	693.
Lebanon	Cincinnati Northern R. R.	709.
Morrow	Cincinnati & Musk. V. R. R.	666.

WILLIAMS COUNTY.

STATION.	AUTHORITY.	ELEVATION.
Bear Creek	L. S. & M. S. R. R.	698.
Bryan	" " "	765.
Edgerton	" " "	830.
Melbern	" " "	843.
Melbern, summit w of.	" " "	877.
Stryker	" " "	715.

WOOD COUNTY.

Bairdstown	B. & O. R. R.	747.
Bloomdale	" "	756.
Bowling Green	Toledo & Southern R. R.	703.
Bradner	Col. H. V. & Toledo R. R.	693.
Hoyt's Corners	B. & O. R. R.	721.
Le Moyne	Col. H. V. & Toledo R. R.	638.
Millbury Junction	L. S. & M. S. R. R.	615.
Milton Center	Dayton & Michigan R. R.	690.
Montgomery's	" " "	667.
North Baltimore	B. & O. R. R.	740.
Pemberville	Col. H. V. & Toledo R. R.	648.
Perrysburg	Dayton & Michigan R. R.	622.
Portage	Toledo & Southern R. R.	686.
Rising Sun	Col. H. V. & Toledo R. R.	707.
Tontogany	Dayton & Michigan R. R.	652.
Walbridge	Col. H. V. & Toledo R. R.	620.

WYANDOT COUNTY.

Carey	I. B. & W. R. R.	818.
Fowler	Col. H. V. & Toledo R. R.	899.
Kirby	Pitts. Ft. W. & Chicago R. R.	882.
Nevada	" " " "	932.
Upper Sandusky	" " " "	860.

TABLE GIVING ELEVATIONS ABOVE SEA LEVEL IN NORTHERN INDIANA.

STATION.	AUTHORITY.	ELEVATION.
Albion	B. P. & C. R. R	927.
Alexandria	L. E. & W. R. R	857.
Anderson	C., C., C. & I. R. R	880.
Angola	Ft. W., J. & S. R. R	1052.
Auburn	" "	872.
Bloomingsport	I., B. & W. R. R	1225.
Bluffton	Ft. W. M. & C. R.R	837.
Brightwood	C., C., C. & I. R.R	792.
Bristol	L. S. & M. S. R. R	785.
Bunker Hill	Pan Handle R. R	800.
Butler	L. S. & M. S. R. R	863.
Cambridge City	P., C. & St. L. R. R	841.
Cassville	Pan Handle R. R	684.
Cedar Creek	Eel River R. R	861.
Collamer	" " "	795.
Collins	" " "	870.
Columbia City	P., Ft. W. & C. R. R	836.
Corunna	L. S. & M. S. R. R	957.
Crown Point Station	Pan Handle R. R	714.
Dayton	L. E. & W. R. R	648.
Decatur	C., R. & Ft. W. R. R	807.
Dunlaps	L. S. & M. S. R. R	748.
Elkhart	" " " " " " "	755.
English Lake	P., Ft. W. & C. R. R	663.
Fairmount	C., W. & M. R. R	893.
Foresters	L. S. & M. S. R. R	852.
Fortville	C., C., C. & I. R. R	857.
Ft. Wayne	P., Ft. W. & C. R. R	775.
Frankfort	L. E. & W. R. R	841.
Fremont	Ft. W., J. & S. R. R	1055.
Gebhard's	Pan Handle R. R	762.
Gillman	L. E. & W. R. R	852.
Goldsmith	" " " " " "	903.
Goshen	L. S. & M. S. R. R	789.

STATION.	AUTHORITY.	ELEVATION.
Gundrum	Pan Handle R. R	710.
Harrisville	C., C., C. & I. R. R	1101.
Hobart	P., Ft. W. & C. R. R	623.
Hobbs	L. E. & W. R. R	867.
Holmesville	L. S. & M. S. R. R	800.
Huntington	T., W. & W. R. R	734.
Indianapolis	C., C., C. & I. R. R	709.
Jonesboro	Pan Handle R. R	846.
Kendallville	L. S. & M. S. R. R	974.
Kennard	I., B. & W. R. R	1057.
LaCrosse	Pan Handle R. R	675.
LaGrange	G. R. & Indiana R. R	915.
La Porte	L. S. & M. S. R. R	811.
Ligonier	" " "	886.
Lima	G. R. & Indiana R. R	882.
Lisbon	" " "	1022.
Logansport	W., St. L. & P. R. R	606.
Losantville	I. B. & W. R. R	1140.
Marion	Pan Handle R. R	811.
Mexico	Eel River R. R	700.
Michigan City	Michigan Central R. R	603.
Millersburg	L. S. & M. S. R. R	886.
Monticello	T., P. & W. R. R	672.
Montgomery	L. E. & W. R. R	672.
Mooresville	Eel River R. R	877.
Muncie	C., C., C. & I. R. R	948.
New Haven	T., W. & W. R. R	753.
Ossian	Ft. W., M. & C. R. R	831.
Pendleton	C., C., C. & I. R. R	847.
Peru	W., St. L. & P. R. R	655.
Plymouth	P., Ft. W. & C. R. R	781.
Portland, low water Wabash	W. & E. Canal	667.
Sedan	L. S. & M. S. R. R	923.
Selma	C., C., C. & I. R. R	1005.
South Bend	L. S. & M. S. R. R	725.
South Whitley	Eel River R. R	808.

STATION.	AUTHORITY.	ELEVATION.
Star City	Pan Handle R. R	706.
Syracuse	B., P. & C. R. R	870.
Teegarden	" " "	794.
Terra Coupee	L. S. & M. S. R. R	760.
Tipton	L. E. & W. R. R	868.
Turkey Lake, high water	B., P. & C. R. R	868.
Valparaiso	P., F. W. & C. R. R	738.
Wabash	W., St. L. & P. R. R	735.
Warren	L. S. & M. S. R. R	731.
Warsaw	P., Ft. W. & C. R. R	824.
Waterloo	L. S. & M. S. R. R	897.
Wawaka	" " "	896.
West River	I.. B. & W. R. R	1110.
Winamac	Pan Handle R. R	713.
Winchester	C., C., C. & I. R. R	1089.

ABBREVIATIONS.

B. P. & C. R. R..............................Baltimore, Pittsburgh & Chicago.
C. C. C. & I. R. R..............Cleveland, Columbus, Cincinnati & Indianapolis
C. R. & Ft. W. R. R......................Cincinnati, Richmond & Fort Wayne
C. W. & M. R. R..............................Cincinnati Wabash & Michigan
Ft. W. J. & S. R. R..........................Fort Wayne, Jackson & Saginaw
Ft. W. M. & C. R. R........................Fort Wayne, Muncie & Cincinnati
G. R. & Ind. R. R...................................Grand Rapids & Indiana
I. B. & W. R. R..........................Indianapolis, Bloomington & Western
L. E. & W. R. R.......................................Lake Erie & Western
L. S. & M. S. R. R..........................Lake Shore & Michigan Southern
P. C. & St. L. R. R..........................Pittsburgh, Cincinnati & St. Louis
P. Ft. W. & C. R. R........................Pittsburgh, Fort Wayne & Chicago
T. W. & W. R. R.................................Toledo, Wabash & Western
W. St. L, & P. R. R..............................Wabash, St. Louis & Pacific

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